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(21) International Application Number: PCT/GB98/02638 (22) International Filing Date: 2 September 1998 (02.09.98) (30) Priority Data: <table border="0"> <tr> <td>9718775.1</td> <td>5 September 1997 (05.09.97)</td> <td>GB</td> </tr> <tr> <td>9722104.8</td> <td>21 October 1997 (21.10.97)</td> <td>GB</td> </tr> <tr> <td>9805336.6</td> <td>12 March 1998 (12.03.98)</td> <td>GB</td> </tr> <tr> <td>9806106.2</td> <td>20 March 1998 (20.03.98)</td> <td>GB</td> </tr> <tr> <td>9806661.6</td> <td>27 March 1998 (27.03.98)</td> <td>GB</td> </tr> <tr> <td>9809598.7</td> <td>7 May 1998 (07.05.98)</td> <td>GB</td> </tr> </table> (71) Applicant (for all designated States except US): BP CHEMICALS LIMITED [GB/GB]; Britannic House, 1 Finsbury Circus, London EC2M 7BA (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): BRITOVSEK, George, Johan, Peter [NL/GB]; 14 De Montfort Road, Streatham Hill, London SW16 1LZ (GB). DORER, Birgit, Angelika [DE/GB]; Chatford, Old Farm Road, Hampton, Middlesex TW12 3QU (GB). GIBSON, Vernon, Charles [GB/GB]; Flat 2, 46 Prince's Gate, Exhibition Road, London SW7 2QA (GB). KIMBERLEY, Brian, Stephen [GB/GB]; 12 Chaplin Crescent, Sunbury-on-Thames, Middlesex TW16		9718775.1	5 September 1997 (05.09.97)	GB	9722104.8	21 October 1997 (21.10.97)	GB	9805336.6	12 March 1998 (12.03.98)	GB	9806106.2	20 March 1998 (20.03.98)	GB	9806661.6	27 March 1998 (27.03.98)	GB	9809598.7	7 May 1998 (07.05.98)	GB	(74) Agent: SMITH, Julian, Philip, Howard; BP International Limited, Group Patents & Agreements, Chertsey Road, Sunbury-on-Thames, Middlesex TW16 7LN (GB). (81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>
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(54) Title: POLYMERISATION CATALYSTS <div style="text-align: center;"> </div> <p style="text-align: right;">(B)</p>																				
(57) Abstract <p>Catalyst systems useful for the polymerisation of 1-olefins are disclosed, which contain nitrogen-containing transition metal compounds comprising the skeletal unit depicted in Formula (B), wherein M is Fe[II], Fe[III], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴ and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.</p>																				

POLYMERISATION CATALYSTS

The present invention relates to transition metal-based polymerisation catalysts and to their use in the polymerisation and copolymerisation of olefins.

The use of certain transition metal compounds to polymerise 1-olefins, for example, ethylene, is well established in the prior art. The use of Ziegler-Natta catalysts, for example, those catalysts produced by activating titanium halides with organometallic compounds such as triethylaluminium, is fundamental to many commercial processes for manufacturing polyolefins. Over the last twenty or thirty years, advances in the technology have led to the development of Ziegler-Natta catalysts which have such high activities that olefin polymers and copolymers containing very low concentrations of residual catalyst can be produced directly in commercial polymerisation processes. The quantities of residual catalyst remaining in the produced polymer are so small as to render unnecessary their separation and removal for most commercial applications. Such processes can be operated by polymerising the monomers in the gas phase, or in solution or in suspension in a liquid hydrocarbon diluent. Polymerisation of the monomers can be carried out in the gas phase (the "gas phase process"), for example by fluidising under polymerisation conditions a bed comprising the target polyolefin powder and particles of the desired catalyst using a fluidising gas stream comprising the gaseous monomer. In the so-called "solution process" the (co)polymerisation is conducted by introducing the monomer into a solution or suspension of the catalyst in a liquid hydrocarbon diluent under conditions of temperature and pressure such that the produced polyolefin forms as a solution in the hydrocarbon diluent. In the "slurry process" the temperature, pressure and choice of diluent are such that the produced polymer forms as a suspension in the liquid hydrocarbon diluent. These processes are generally operated at relatively low pressures (for example 10-50

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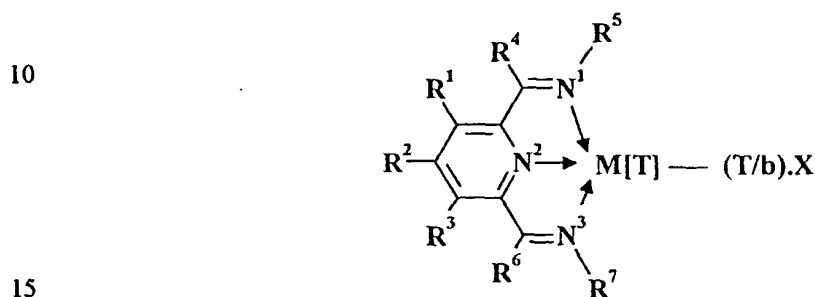
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flexible film and solid polyolefins having high stiffness.

The present invention provides a polymerisation catalyst comprising

(1) a nitrogen-containing transition metal compound having the following Formula B, and

5 (2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,



Formula B

wherein M[T] is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV],
 20 Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or
 ionically bonded to the transition metal M; T is the oxidation state of the transition
 metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶
 are independently selected from hydrogen, halogen, hydrocarbyl, substituted
 hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl;

25 and such that (1)

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen,
 halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted
 heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl,
 substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said
 30 two or more can be linked to form one or more cyclic substituents,

or such that (2)

when M is Fe, Co, Mn or Ru, then R⁵ is represented by the group "P" and R⁷ is
 represented by the group "Q" as follows:

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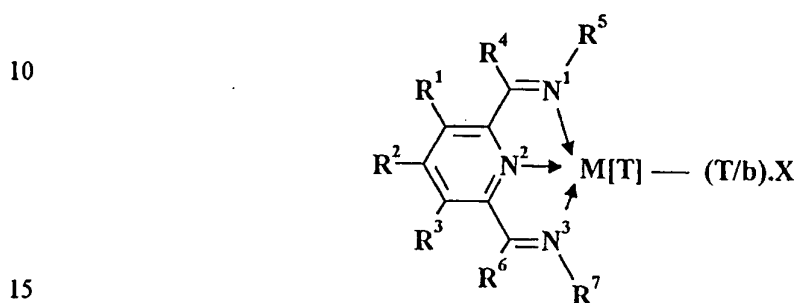
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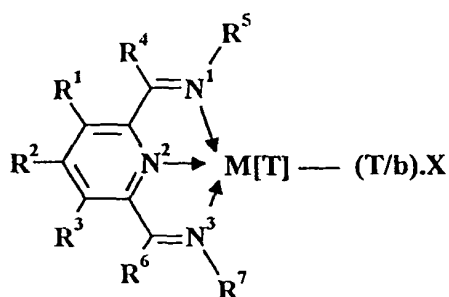
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Formula B

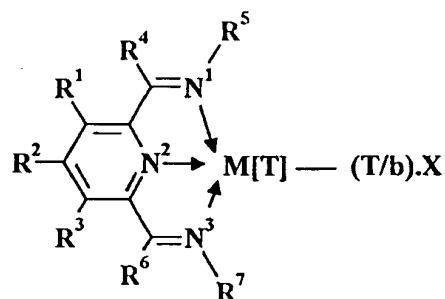
wherein M is Fe[II], Fe[III], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴ and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.

When any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

A further embodiment of the present invention provides a polymerisation catalyst comprising

- (1) a nitrogen-containing transition metal compound of Formula Z and
- (2) an activating quantity of an activator compound selected from

organoaluminium compounds and hydrocarbylboron compounds,



Formula B

wherein M is Fe[II], Fe[III], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴ and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.

When any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

A further embodiment of the present invention provides a polymerisation catalyst comprising

- (1) a nitrogen-containing transition metal compound of Formula Z and
- (2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,

and Z of the present invention are preferably independently selected from hydrogen and C₁ to C₈ hydrocarbyl, for example, methyl, ethyl, n-propyl, n-butyl, n-hexyl, and n-octyl. In Formula B, R⁵ and R⁷ are preferably independently selected from substituted or unsubstituted alicyclic, heterocyclic or aromatic groups, for example,
 5 phenyl, 1-naphthyl, 2-naphthyl, 2-methylphenyl, 2-ethylphenyl, 2,6-diisopropylphenyl, 2,3-diisopropylphenyl, 2,4-diisopropylphenyl, 2,6-di-n-butylphenyl, 2,6-dimethylphenyl, 2,3-dimethylphenyl, 2,4-dimethylphenyl, 2-t-butylphenyl, 2,6-diphenylphenyl, 2,4,6-trimethylphenyl, 2,6-trifluoromethylphenyl, 4-bromo-2,6-dimethylphenyl, 3,5 dichloro-2,6-diethylphenyl,
 10 and 2,6-bis(2,6-dimethylphenyl)phenyl, cyclohexyl and pyridinyl.

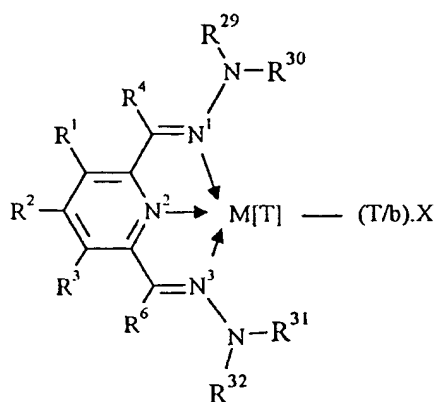
The ring systems P and Q in Formula Z are preferably independently 2,6-hydrocarbylphenyl or fused-ring polyaromatic, for example, 1-naphthyl, 2-naphthyl, 1-phenanthrenyl and 8-quinolinyl.

Another embodiment of the present invention provides a polymerisation
 15 catalyst comprising

- (1) a nitrogen-containing transition metal compound of Formula T and
- (2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,

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25



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Formula T

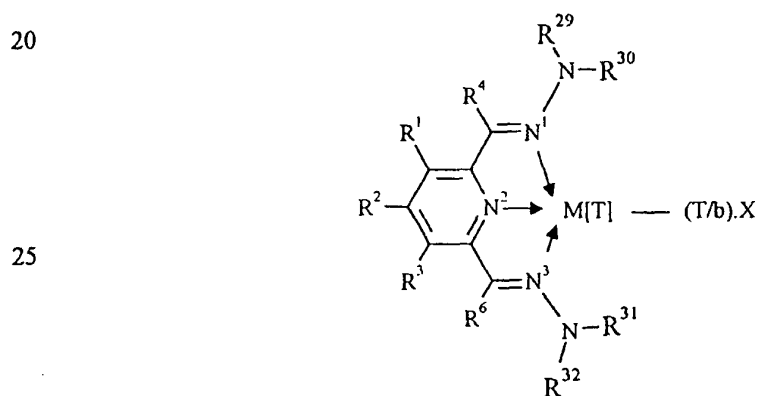
wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition
 35 metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R²⁹ to R³²

and Z of the present invention are preferably independently selected from hydrogen and C₁ to C₈ hydrocarbyl, for example, methyl, ethyl, n-propyl, n-butyl, n-hexyl, and n-octyl. In Formula B, R⁵ and R⁷ are preferably independently selected from substituted or unsubstituted alicyclic, heterocyclic or aromatic groups, for example,
 5 phenyl, 1-naphthyl, 2-naphthyl, 2-methylphenyl, 2-ethylphenyl, 2,6-diisopropylphenyl, 2,3-diisopropylphenyl, 2,4-diisopropylphenyl, 2,6-di-n-butylphenyl, 2,6-dimethylphenyl, 2,3-dimethylphenyl, 2,4-dimethylphenyl, 2-t-butylphenyl, 2,6-diphenylphenyl, 2,4,6-trimethylphenyl, 2,6-trifluoromethylphenyl, 4-bromo-2,6-dimethylphenyl, 3,5 dichloro-2,6-diethylphenyl,
 10 and 2,6-bis(2,6-dimethylphenyl)phenyl, cyclohexyl and pyridinyl.

The ring systems P and Q in Formula Z are preferably independently 2,6-hydrocarbylphenyl or fused-ring polyaromatic, for example, 1-naphthyl, 2-naphthyl, 1-phenanthrenyl and 8-quinolinyl.

Another embodiment of the present invention provides a polymerisation
 15 catalyst comprising

- (1) a nitrogen-containing transition metal compound of Formula T and
- (2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,



30 Formula T

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or
 35 ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R²⁹ to R³²

illustrated above.

The atom or group represented by X in the compounds of Formulae B, Z, T and W can be, for example, selected from halide, sulphate, nitrate, thiolate, thiocarboxylate, BF_4^- , PF_6^- , hydride, hydrocarbyloxy, carboxylate, hydrocarbyl, substituted hydrocarbyl and heterohydrocarbyl. Examples of such atoms or groups are chloride, bromide, methyl, ethyl, propyl, butyl, octyl, decyl, phenyl, benzyl, methoxide, ethoxide, isopropoxide, tosylate, triflate, formate, acetate, phenoxide and benzoate. Preferred examples of the atom or group X in the compounds of Formula B, Z, T and W are halide, for example, chloride, bromide; hydride; hydrocarbyloxy, for example, methoxide, ethoxide, isopropoxide, phenoxide; carboxylate, for example, formate, acetate, benzoate; hydrocarbyl, for example, methyl, ethyl, propyl, butyl, octyl, decyl, phenyl, benzyl; substituted hydrocarbyl; heterohydrocarbyl; tosylate; and triflate. Preferably X is selected from halide, hydride and hydrocarbyl. Chloride is particularly preferred.

The following are examples of nitrogen-containing transition metal complexes that can be employed in the catalyst of the present invention:

- 2,6-diacetylpyridinebis(2,6-diisopropylanil) FeCl_2
- 2,6-diacetylpyridine(2,6-diisopropylanil) MnCl_2
- 2,6-diacetylpyridine(2,6-diisopropylanil) CoCl_2
- 2,6-diacetylpyridinebis(2-tert.-butylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,3-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2-methylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,4-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,6-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-dimethylanil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-diethylanil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-diisopropylanil) FeCl_2
- 2,6-dialdiminepyridinebis(1-naphthyl) FeCl_2 and
- 2,6-bis(1,1-diphenylhydrazone)pyridine. FeCl_2 .

A preferred complex of the present invention is
2,6-diacetylpyridinebis(2,4,6 trimethyl anil) FeCl_2 .

The activator compound for the catalyst of the present invention is suitably selected from organoaluminium compounds and hydrocarbylboron compounds.

Suitable organoaluminium compounds include trialkylaluminium compounds, for

illustrated above.

The atom or group represented by X in the compounds of Formulae B, Z, T and W can be, for example, selected from halide, sulphate, nitrate, thiolate, thiocarboxylate, BF_4^- , PF_6^- , hydride, hydrocarbyloxy, carboxylate, hydrocarbyl, substituted hydrocarbyl and heterohydrocarbyl. Examples of such atoms or groups are chloride, bromide, methyl, ethyl, propyl, butyl, octyl, decyl, phenyl, benzyl, methoxide, ethoxide, isopropoxide, tosylate, triflate, formate, acetate, phenoxide and benzoate. Preferred examples of the atom or group X in the compounds of Formula B, Z, T and W are halide, for example, chloride, bromide; hydride; hydrocarbyloxy, for example, methoxide, ethoxide, isopropoxide, phenoxide; carboxylate, for example, formate, acetate, benzoate; hydrocarbyl, for example, methyl, ethyl, propyl, butyl, octyl, decyl, phenyl, benzyl; substituted hydrocarbyl; heterohydrocarbyl; tosylate; and triflate. Preferably X is selected from halide, hydride and hydrocarbyl. Chloride is particularly preferred.

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- 2,6-diacetylpyridinebis(2,6-diisopropylanil) FeCl_2
- 2,6-diacetylpyridine(2,6-diisopropylanil) MnCl_2
- 2,6-diacetylpyridine(2,6-diisopropylanil) CoCl_2
- 2,6-diacetylpyridinebis(2-tert.-butylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,3-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2-methylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,4-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,6-dimethylanil) FeCl_2
- 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-dimethylanil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-diethylanil) FeCl_2
- 2,6-dialdiminepyridinebis(2,6-diisopropylanil) FeCl_2
- 2,6-dialdiminepyridinebis(1-naphthyl) FeCl_2 and
- 2,6-bis(1,1-diphenylhydrazon)pyridine. FeCl_2 .

A preferred complex of the present invention is

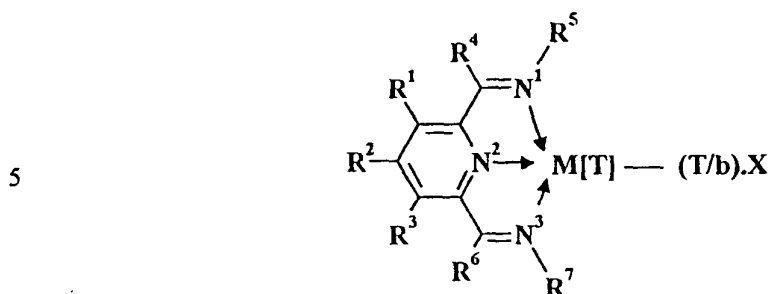
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The activator compound for the catalyst of the present invention is suitably selected from organoaluminium compounds and hydrocarbylboron compounds.

Suitable organoaluminium compounds include trialkylaluminium compounds, for

compounds are preferred. The preferences in relation to the activator compound are the same as expressed above in relation to the catalysts of the present invention. Neutral Lewis bases are well known in the art of Ziegler-Natta catalyst polymerisation technology. Examples of classes of neutral Lewis bases suitably employed in the present invention are unsaturated hydrocarbons, for example, alkenes (other than 1-olefins) or alkynes, primary, secondary and tertiary amines, amides, phosphoramides, phosphines, phosphites, ethers, thioethers, nitriles, carbonyl compounds, for example, esters, ketones, aldehydes, carbon monoxide and carbon dioxide, sulphoxides, sulphones and boroxines. Although 1-olefins are capable of acting as neutral Lewis bases, for the purposes of the present invention they are regarded as monomer or comonomer 1-olefins and not as neutral Lewis bases *per se*. However, alkenes which are internal olefins, for example, 2-butene and cyclohexene are regarded as neutral Lewis bases in the present invention. Preferred Lewis bases are tertiary amines and aromatic esters, for example, dimethylaniline, diethylaniline, tributylamine, ethylbenzoate and benzylbenzoate. In this particular aspect of the present invention, components (1), (2) and (3) of the catalyst system can be brought together simultaneously or in any desired order. However, if components (2) and (3) are compounds which interact together strongly, for example, form a stable compound together, it is preferred to bring together either components (1) and (2) or components (1) and (3) in an initial step before introducing the final defined component. Preferably components (1) and (3) are contacted together before component (2) is introduced. The quantities of components (1) and (2) employed in the preparation of this catalyst system are suitably as described above in relation to the catalysts of the present invention. The quantity of the neutral Lewis Base [component (3)] is preferably such as to provide a ratio of component (1):component (3) in the range 100:1 to 1:1000, most preferably in the range 1:1 to 1:20. Components (1), (2) and (3) of the catalyst system can brought together, for example, as the neat materials, as a suspension or solution of the materials in a suitable diluent or solvent (for example a liquid hydrocarbon), or, if at least one of the components is volatile, by utilising the vapour of that component. The components can be brought together at any desired temperature. Mixing the components together at room temperature is generally satisfactory. Heating to higher temperatures eg up to 120°C can be carried out if desired, eg to achieve better mixing of the components. It is preferred to carry out the bringing together of components (1), (2) and (3) in an

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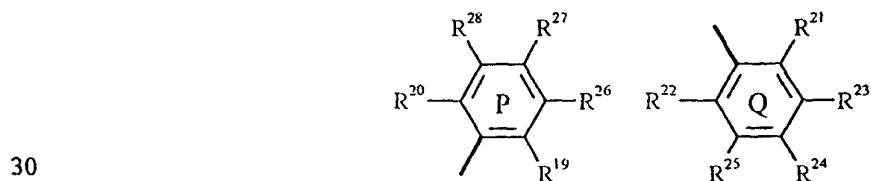
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wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and such that (1):

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents, or such that (2):

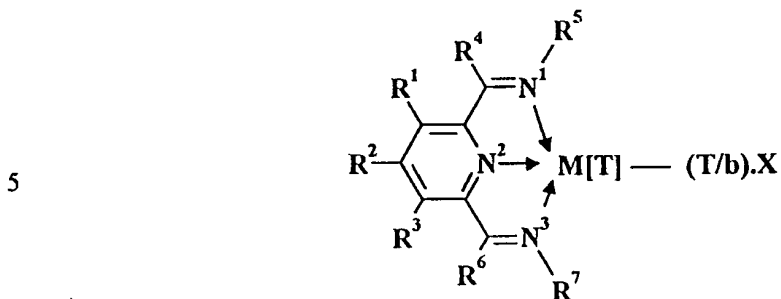
when M is Fe, Co, Mn or Ru, then R⁵ is represented by the group "P" and R⁷ is represented by the group "Q" as follows:

25



wherein R¹⁹ to R²⁸ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted

35



Formula B

10

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl;

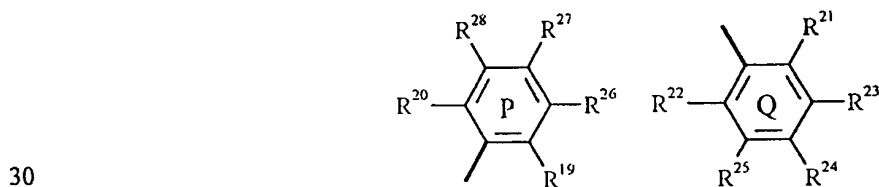
15 and such that (1):

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents,

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wherein R¹⁹ to R²⁸ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted

35

phase or gas phase. If desired, the catalyst can be used to polymerise ethylene under high pressure/high temperature process conditions wherein the polymeric material forms as a melt in supercritical ethylene. Preferably the polymerisation is conducted under gas phase fluidised bed conditions.

5 Slurry phase polymerisation conditions or gas phase polymerisation conditions are particularly useful for the production of high density grades of polyethylene. In these processes the polymerisation conditions can be batch, continuous or semi-continuous. In the slurry phase process and the gas phase process, the catalyst is generally fed to the polymerisation zone in the form of a
10 particulate solid. This solid can be, for example, an undiluted solid catalyst system formed from a nitrogen-containing complex and an activator, or can be the solid complex alone. In the latter situation, the activator can be fed to the polymerisation zone, for example as a solution, separately from or together with the solid complex. Preferably the catalyst system or the transition metal complex
15 component of the catalyst system employed in the slurry polymerisation and gas phase polymerisation is supported on a support material. Most preferably the catalyst system is supported on a support material prior to its introduction into the polymerisation zone. Suitable support materials are, for example, silica, alumina, zirconia, talc, kieselguhr, or magnesia. Impregnation of the support material can
20 be carried out by conventional techniques, for example, by forming a solution or suspension of the catalyst components in a suitable diluent or solvent, and slurring the support material therewith. The support material thus impregnated with catalyst can then be separated from the diluent for example, by filtration or evaporation techniques.

25 In the slurry phase polymerisation process the solid particles of catalyst, or supported catalyst, are fed to a polymerisation zone either as dry powder or as a slurry in the polymerisation diluent. Preferably the particles are fed to a polymerisation zone as a suspension in the polymerisation diluent. The polymerisation zone can be, for example, an autoclave or similar reaction vessel,
30 or a continuous loop reactor, eg of the type well-known in the manufacture of polyethylene by the Phillips Process. When the polymerisation process of the present invention is carried out under slurry conditions the polymerisation is preferably carried out at a temperature above 0°C, most preferably above 15°C. The polymerisation temperature is preferably maintained below the temperature at
35 which the polymer commences to soften or sinter in the presence of the

phase or gas phase. If desired, the catalyst can be used to polymerise ethylene under high pressure/high temperature process conditions wherein the polymeric material forms as a melt in supercritical ethylene. Preferably the polymerisation is conducted under gas phase fluidised bed conditions.

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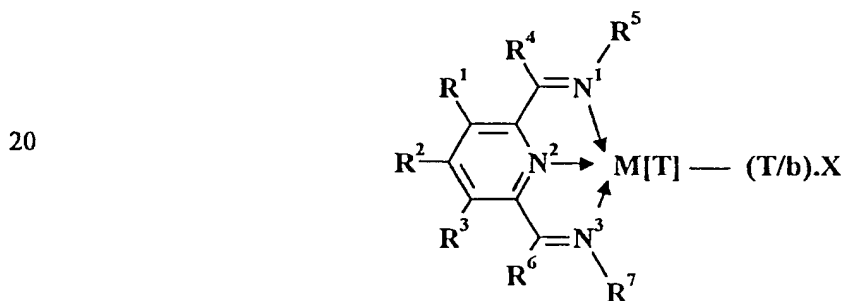
Using a catalyst comprising a nitrogen-containing Fe complex in accordance with the present invention in, for example, a slurry polymerisation, it is possible to obtain polyethylene powder wherein the Fe concentration is, for example, 1.03 to 0.11 parts by weight of Fe per million parts by weight of polyethylene.

5 Suitable monomers for use in the polymerisation process of the present invention are, for example, ethylene, propylene, butene, hexene, methyl methacrylate, methyl acrylate, butyl acrylate, acrylonitrile, vinyl acetate, and styrene. Preferred monomers for homopolymerisation processes are ethylene and propylene. The catalyst can also be used for copolymerising ethylene with other 1-
10 olefins such as propylene, 1-butene, 1-hexene, 4-methylpentene-1, and octene.

Thus the present invention further provides a process comprising contacting ethylene and one or more other 1-olefins with a catalyst comprising

(1) a nitrogen-containing transition metal compound having the following Formula B, and

15 (2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,



25 Formula B

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition
30 metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and such that (1):

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen,
35 halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted

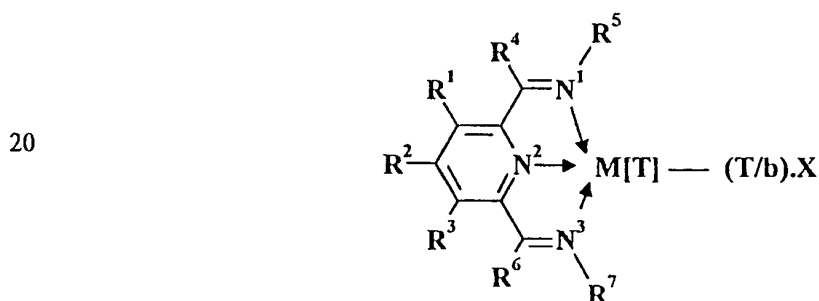
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wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition
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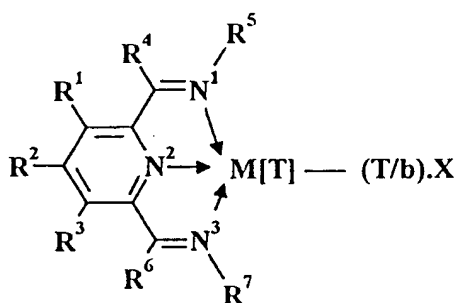
when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen,
35 halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted

ethylene with other monomeric materials, for example, methyl methacrylate, methyl acrylate, butyl acrylate, acrylonitrile, vinyl acetate, and styrene.

A preferred embodiment of the present invention comprises a process for the polymerisation and copolymerisation of 1-olefins comprising contacting the monomeric olefin under polymerisation conditions with a polymerisation catalyst comprising

(1) a nitrogen-containing transition metal compound having the following Formula B, and

(2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,



Formula B

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and such that (1):

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents,

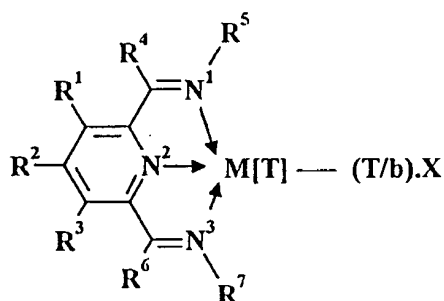
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(2) an activating quantity of an activator compound selected from organoaluminium compounds and hydrocarbylboron compounds,



Formula B

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV], Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and such that (1):

when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents,

or such that (2):

and/or volatile liquid (eg a volatile inert hydrocarbon, or gaseous monomer which has been condensed to form a liquid). The polymer produced in, and isolated from, gas phase processes forms directly a solid in the polymerisation zone and is free from, or substantially free from liquid. As is well known to those skilled in the art, if any liquid is allowed to enter the polymerisation zone of a gas phase polymerisation process the quantity of liquid is small in relation to the quantity of polymer present in the polymerisation zone. This is in contrast to "solution phase" processes wherein the polymer is formed dissolved in a solvent, and "slurry phase" processes wherein the polymer forms as a suspension in a liquid diluent.

10 The gas phase process can be operated under batch, semi-batch, or so-called "continuous" conditions. It is preferred to operate under conditions such that monomer is continuously recycled to an agitated polymerisation zone containing polymerisation catalyst, make-up monomer being provided to replace polymerised monomer, and continuously or intermittently withdrawing produced polymer from the polymerisation zone at a rate comparable to the rate of formation of the polymer, fresh catalyst being added to the polymerisation zone to replace the catalyst withdrawn from the polymerisation zone with the produced polymer.

15 In the preferred embodiment of the gas phase polymerisation process of the present invention, the gas phase polymerisation conditions are preferably gas phase fluidised bed polymerisation conditions.

20 Methods for operating gas phase fluidised bed processes for making polyethylene and ethylene copolymers are well known in the art. The process can be operated, for example, in a vertical cylindrical reactor equipped with a perforated distribution plate to support the bed and to distribute the incoming fluidising gas stream through the bed. The fluidising gas circulating through the bed serves to remove the heat of polymerisation from the bed and to supply monomer for polymerisation in the bed. Thus the fluidising gas generally comprises the monomer(s) normally together with some inert gas (eg nitrogen) and optionally with hydrogen as molecular weight modifier. The hot fluidising gas emerging from the top of the bed is led optionally through a velocity reduction zone (this can be a cylindrical portion of the reactor having a wider diameter) and, if desired, a cyclone and or filters to disentrain fine solid particles from the gas stream. The hot gas is then led to a heat exchanger to remove at least part of the heat of polymerisation. Catalyst is preferably fed continuously or at regular intervals to the bed. At start up of the process, the bed comprises fluidisable

and/or volatile liquid (eg a volatile inert hydrocarbon, or gaseous monomer which has been condensed to form a liquid). The polymer produced in, and isolated from, gas phase processes forms directly a solid in the polymerisation zone and is free from, or substantially free from liquid. As is well known to those skilled in the art, if any liquid is allowed to enter the polymerisation zone of a gas phase polymerisation process the quantity of liquid is small in relation to the quantity of polymer present in the polymerisation zone. This is in contrast to "solution phase" processes wherein the polymer is formed dissolved in a solvent, and "slurry phase" processes wherein the polymer forms as a suspension in a liquid diluent.

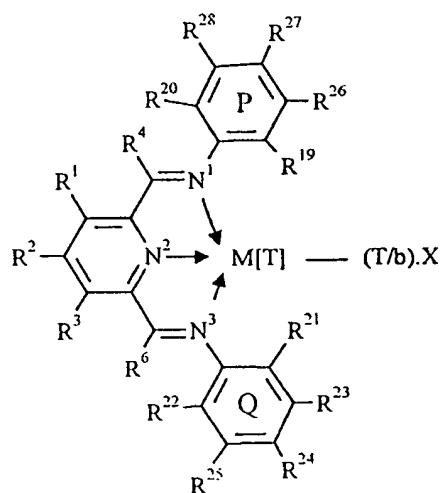
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polymerisation reaction zone in liquid form, for example, as a solution in an inert liquid diluent. Thus, for example, the transition metal component, or the activator component, or both of these components can be dissolved or slurried in a liquid diluent and fed to the polymerisation zone. Under these circumstances it is preferred the liquid containing the component(s) is sprayed as fine droplets into the polymerisation zone. The droplet diameter is preferably within the range 1 to 1000 microns. EP-A-0593083, the teaching of which is hereby incorporated into this specification, discloses a process for introducing a polymerisation catalyst into a gas phase polymerisation. The methods disclosed in EP-A-0593083 can be suitably employed in the polymerisation process of the present invention if desired.

The present invention further provides a novel nitrogen-containing transition metal compound comprising the skeletal unit depicted in Formula Z:

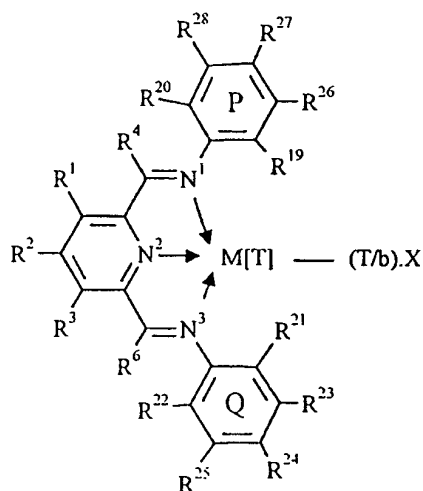


Formula Z

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents; with the proviso that at least one of

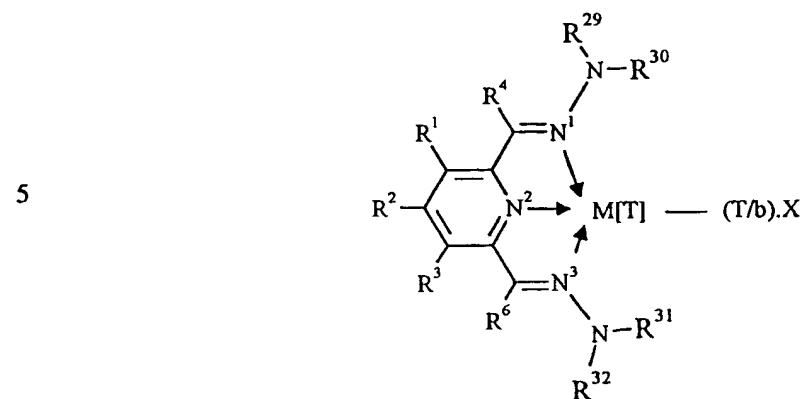
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The present invention further provides a novel nitrogen-containing transition metal compound comprising the skeletal unit depicted in Formula Z:



Formula Z

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents; with the proviso that at least one of



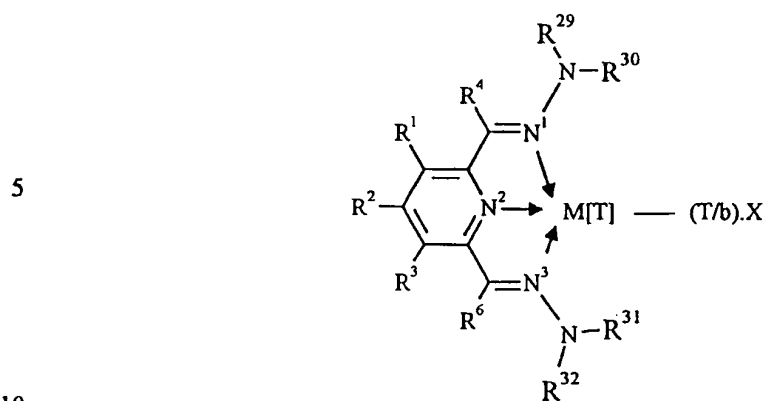
Formula T

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III],
 15 Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or
 ionically bonded to the transition metal M; T is the oxidation state of the transition
 metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R²⁹ to R³²
 are independently selected from hydrogen, halogen, hydrocarbyl, substituted
 hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or
 20 more of R¹ to R⁴, R⁶ and R²⁹ to R³² are hydrocarbyl, substituted hydrocarbyl,
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 linked to form one or more cyclic substituents.

A further aspect of the invention comprises the use of the compounds
 defined previously as catalysts for the polymerisation or co-polymerisation of 1-
 25 olefins.

The following are examples of novel nitrogen-containing transition metal
 complexes of the present invention:

- 2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂
- 2,6-diacetylpyridine(2,6-diisopropylanil)MnCl₂
- 30 2,6-diacetylpyridine(2,6-diisopropylanil)CoCl₂
- 2,6-diacetylpyridinebis(2-tert.-butylanil)FeCl₂
- 2,6-diacetylpyridinebis(2,3-dimethylanil)FeCl₂
- 2,6-diacetylpyridinebis(2-methylanil)FeCl₂
- 2,6-diacetylpyridinebis(2,4-dimethylanil)FeCl₂
- 35 2,6-diacetylpyridinebis(2,6-dimethylanil)FeCl₂



Formula T

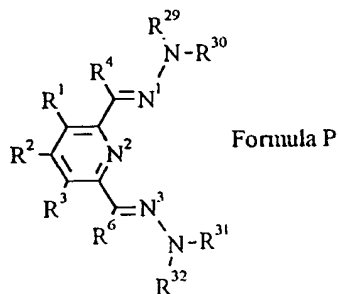
wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III],
 15 Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or
 ionically bonded to the transition metal M; T is the oxidation state of the transition
 metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R²⁹ to R³²
 are independently selected from hydrogen, halogen, hydrocarbyl, substituted
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 30 2,6-diacetylpyridine(2,6-diisopropylanil)CoCl₂
 2,6-diacetylpyridinebis(2-tert.-butylanil)FeCl₂
 2,6-diacetylpyridinebis(2,3-dimethylanil)FeCl₂
 2,6-diacetylpyridinebis(2-methylanil)FeCl₂
 2,6-diacetylpyridinebis(2,4-dimethylanil)FeCl₂
 35 2,6-diacetylpyridinebis(2,6-dimethylanil)FeCl₂

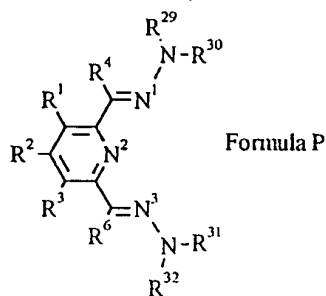
The present invention further provides novel compounds useful for making polymerisation catalysts comprising a compound having the general Formula P as follows:



wherein R^1 to R^4 , R^6 and R^{29} to R^{32} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{29} to R^{32} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents. Preferably R^{29} , R^{30} , R^{31} and R^{32} are hydrocarbyl. Most preferably at least one of R^{29} and R^{30} , and at least one of R^{31} and R^{32} are aryl groups, for example, phenyl, naphthyl, or substituted phenyl. Ligands of the type shown in Formula P can be prepared by well-known methods, for example by reaction of a substituted or unsubstituted 2,6-di(carboxaldehyde)pyridine or 2,6-diacetylpyridine compound (ie having the appropriate R^1 , R^2 , R^3 , R^4 and R^6 substituents) with two molar equivalents of a hydrazine compound bearing the desired substituents R^{29} , R^{30} , R^{31} and R^{32} .

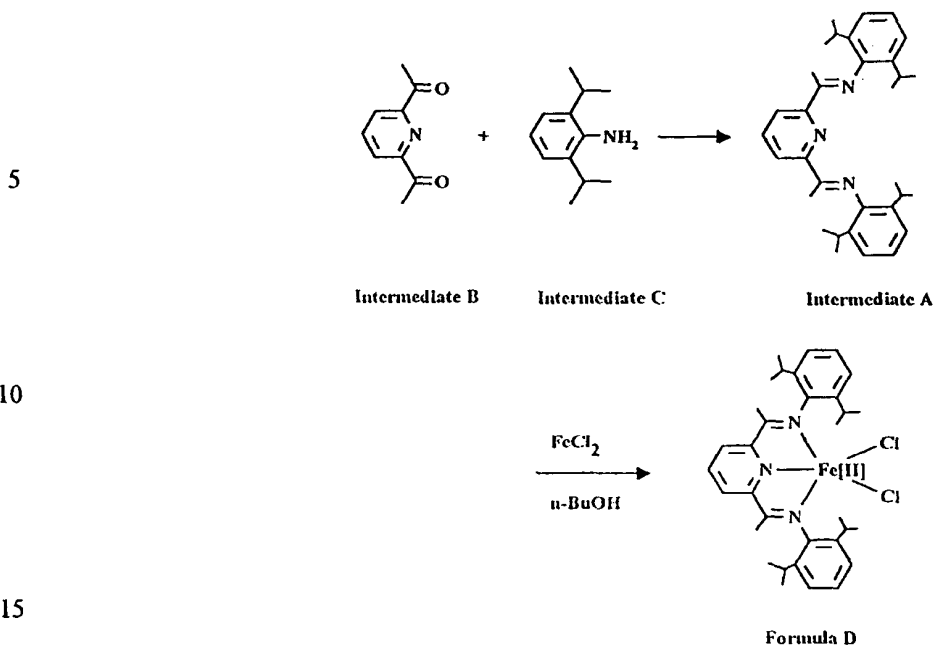
Thus ligands of the type illustrated, for example, in Formulae B, Z, T, E and P can generally be prepared by condensation reactions between bis(carbonyl)pyridine compounds and appropriate amines or hydrazines. Such reactions can be catalysed, for example, by acids, for example, acetic acid or toluene-p-sulphonic acid. During reactions of this type it is normally advantageous to remove from the reaction zone the water eliminated by the reaction of the carbonyl groups with the $-NH_2$ groups. In the preparation of ligands using this type of reaction, it is preferred to take off the water by refluxing the reaction mixture with an azeotrope-forming water-immiscible liquid, and separating and

The present invention further provides novel compounds useful for making polymerisation catalysts comprising a compound having the general Formula P as follows:



wherein R^1 to R^4 , R^6 and R^{29} to R^{32} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{29} to R^{32} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents. Preferably R^{29} , R^{30} , R^{31} and R^{32} are hydrocarbyl. Most preferably at least one of R^{29} and R^{30} , and at least one of R^{31} and R^{32} are aryl groups, for example, phenyl, naphthyl, or substituted phenyl. Ligands of the type shown in Formula P can be prepared by well-known methods, for example by reaction of a substituted or unsubstituted 2,6-di(carboxaldehyde)pyridine or 2,6-diacetylpyridine compound (ie having the appropriate R^1 , R^2 , R^3 , R^4 and R^6 substituents) with two molar equivalents of a hydrazine compound bearing the desired substituents R^{29} , R^{30} , R^{31} and R^{32} .

Thus ligands of the type illustrated, for example, in Formulae B, Z, T, E and P can generally be prepared by condensation reactions between bis(carbonyl)pyridine compounds and appropriate amines or hydrazines. Such reactions can be catalysed, for example, by acids, for example, acetic acid or toluene-p-sulphonic acid. During reactions of this type it is normally advantageous to remove from the reaction zone the water eliminated by the reaction of the carbonyl groups with the $-NH_2$ groups. In the preparation of ligands using this type of reaction, it is preferred to take off the water by refluxing the reaction mixture with an azeotrope-forming water-immiscible liquid, and separating and



Preparation of the Formula D compound

[2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂]

20 FeCl₂ (0.24 g; 1.89 mmol) was dissolved in hot n-butanol (20 ml) at 80 °C. A suspension of 2,6-diacetylpyridinebis(2,6-diisopropylanil) (0.92 g; 1.89 mmol) in n-butanol was added dropwise at 80 °C. The reaction mixture turned blue. After stirring at 80 °C for 15 minutes the reaction was allowed to cool down to room temperature. The reaction volume was reduced to a few ml, and petroleum ether

25 (40/60) was added to precipitate the product (a blue powder), which was subsequently washed three times with 10 ml petroleum ether (40/60). The yield was 0.93 g (81 %).

Mass spectrum: *m/z* 607 [M]⁺, 572 [M-Cl]⁺, 482 [M-FeCl₂]⁺.

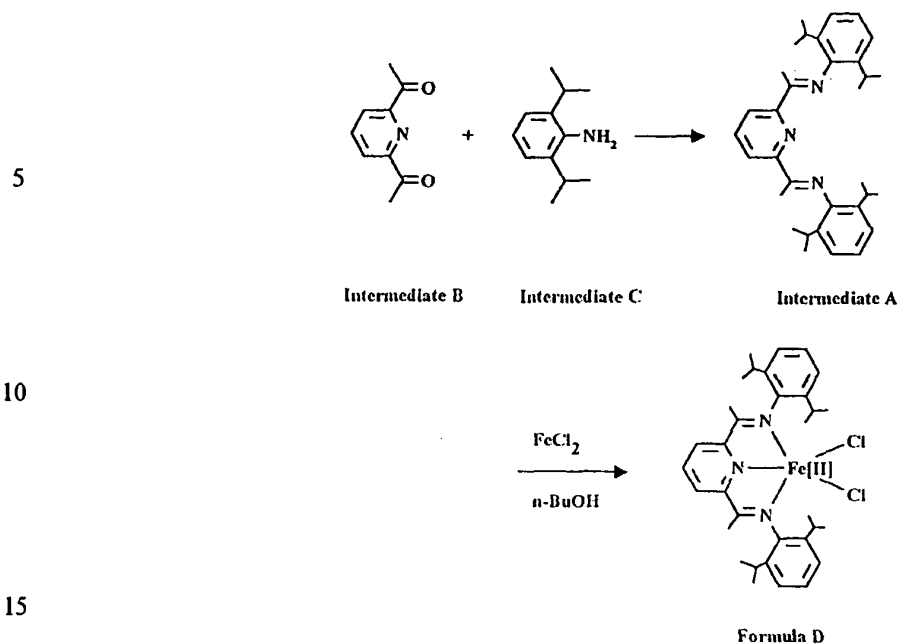
Analysis - Calculated: for C₃₃H₄₃N₃FeCl₂: C, 65.14; H, 7.12; N, 6.91.

30 Found: C, 64.19; H, 6.90; N, 6.70.

Runs 1.1 to 1.6 - Polymerisation Tests

The polymerisation tests described in Runs 1.1 to 1.6 were carried out using the following procedure. The catalyst of Formula D and cocatalyst (methylalumoxane - "MAO") was added to a Schlenk tube and dissolved in

35 toluene (40 ml). The tube was purged with ethylene and the contents were



Preparation of the Formula D compound

[2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂]

20 FeCl₂ (0.24 g; 1.89 mmol) was dissolved in hot n-butanol (20 ml) at 80 °C. A suspension of 2,6-diacetylpyridinebis(2,6-diisopropylanil) (0.92 g; 1.89 mmol) in n-butanol was added dropwise at 80 °C. The reaction mixture turned blue. After stirring at 80 °C for 15 minutes the reaction was allowed to cool down to room temperature. The reaction volume was reduced to a few ml, and petroleum ether (40/60) was added to precipitate the product (a blue powder), which was subsequently washed three times with 10 ml petroleum ether (40/60). The yield was 0.93 g (81 %).

Mass spectrum: *m/z* 607 [M]⁺, 572 [M-Cl]⁺, 482 [M-FeCl₂]⁺.

Analysis - Calculated: for C₃₃H₄₃N₃FeCl₂: C, 65.14; H, 7.12; N, 6.91.

30 Found: C, 64.19; H, 6.90; N, 6.70.

Runs 1.1 to 1.6 - Polymerisation Tests

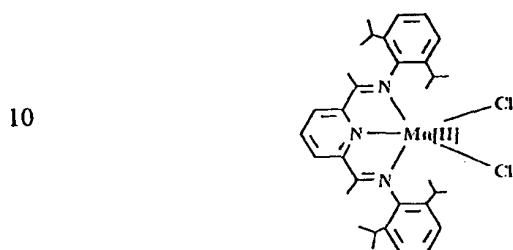
The polymerisation tests described in Runs 1.1 to 1.6 were carried out using the following procedure. The catalyst of Formula D and cocatalyst (methylalumoxane - "MAO") was added to a Schlenk tube and dissolved in 35 toluene (40 ml). The tube was purged with ethylene and the contents were

per millimole of catalyst per hour per bar pressure of ethylene).

4. In Run 1.5, the cocatalyst was provided by 1 millequivalent of tris(perfluorophenyl)boron and 20 milliequivalents of triisobutylaluminium.

Example 2

- 5 The manganese[II] compound illustrated in the following diagram was prepared and tested for catalytic activity in the polymerisation of ethylene.



FORMULA J

15

Preparation of Manganese(II) compound with Formula J [(2,6-diacetylpyridine(2,6-diisopropylanil)MnCl₂]

A suspension of MnCl₂·4H₂O (0.50 g, 2.53 mmol) and Intermediate A (1.22 g, 2.53 mmol) was refluxed in acetonitrile (50 ml) for 12 h to give an orange solution.

- 20 On cooling to room temperature orange crystals were obtained of the Mn(II) compound of Formula J; yield 59%. Microanalysis data supported the Formula J empirical formula. The FAB mass spectrum displayed a highest peak corresponding to an *M*+·Cl (571) ion.

Polymerisation test - Run 2.1

- 25 A 1.8 M solution of diethylaluminium chloride (DEAC) in toluene (0.50 ml, 0.9 mmol, 30 equivalents) was added via syringe to a stirred suspension of the Formula J Mn(II) compound (18 mg, 0.03 mmol) in toluene (40 ml). The produced catalyst solution was degassed under reduced pressure and back-filled with an atmosphere of ethylene. During the run time of 20 h the solution was left open to a supply of
- 30 ethylene at one atmosphere and stirred vigorously at 25 °C. The polymerisation was terminated by the addition of dilute HCl (ca. 40 ml) and then stirred for 30 minutes to dissolve the alkylaluminium residues. Solid polyethylene was filtered from the reaction, washed with an acidified methanol solution and dried in vacuo at 40°C overnight. Yield 0.011 g. Activity was 0.2 gmmol⁻¹hr⁻¹bar⁻¹.

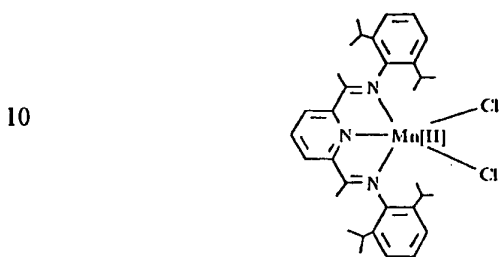
35

per millimole of catalyst per hour per bar pressure of ethylene).

4. In Run 1.5, the cocatalyst was provided by 1 millequivalent of tris(perfluorophenyl)boron and 20 milliequivalents of triisobutylaluminium.

Example 2

- 5 The manganese[II] compound illustrated in the following diagram was prepared and tested for catalytic activity in the polymerisation of ethylene.



FORMULA J

15

Preparation of Manganese(II) compound with Formula J [(2,6-diacetylpyridine(2,6-diisopropylanil)MnCl₂]

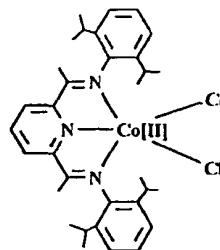
A suspension of MnCl₂·4H₂O (0.50 g, 2.53 mmol) and Intermediate A (1.22 g, 2.53 mmol) was refluxed in acetonitrile (50 ml) for 12 h to give an orange solution.

- 20 On cooling to room temperature orange crystals were obtained of the Mn(II) compound of Formula J; yield 59%. Microanalysis data supported the Formula J empirical formula. The FAB mass spectrum displayed a highest peak corresponding to an *M*⁺-Cl (571) ion.

Polymerisation test - Run 2.1

- 25 A 1.8 M solution of diethylaluminium chloride (DEAC) in toluene (0.50 ml, 0.9 mmol, 30 equivalents) was added via syringe to a stirred suspension of the Formula J Mn(II) compound (18 mg, 0.03 mmol) in toluene (40 ml). The produced catalyst solution was degassed under reduced pressure and back-filled with an atmosphere of ethylene. During the run time of 20 h the solution was left open to a supply of
- 30 ethylene at one atmosphere and stirred vigorously at 25 °C. The polymerisation was terminated by the addition of dilute HCl (ca. 40 ml) and then stirred for 30 minutes to dissolve the alkylaluminium residues. Solid polyethylene was filtered from the reaction, washed with an acidified methanol solution and dried in vacuo at 40°C overnight. Yield 0.011 g. Activity was 0.2 gmmol⁻¹hr⁻¹bar⁻¹.

35



FORMULA K

Examples 4 to 9 - Preparation of Iron Complexes10 Example 44.1 - Preparation of 2,6-diacetylpyridinebis(2-tert.-butylanil)

To a solution of 2,6-diacetylpyridine (0.54 g; 3.31 mmol) in absolute ethanol (20 ml) was added 2-tertiarybutylaniline (1.23 g; 2.5 eq.). After the addition of 2 drops of acetic acid (glacial) the solution was refluxed overnight. Upon cooling to room temperature the product crystallised from ethanol. The product was filtered, washed with cold ethanol and dried in a vacuum oven (50°C) overnight. The yield was 1.07 g (76 %). Analysis ¹H NMR(CDCl₃): 8.43, 7.93, 7.44, 7.21, 7.09, 6.56 (m, 7H, ArH, pyrH), 2.43 (s, 6H, N=CCH₃), 1.39 (s, 18H, CCH₃).

4.2 - Preparation of 2,6-diacetylpyridinebis(2-tert.-butylanil)FeCl₂

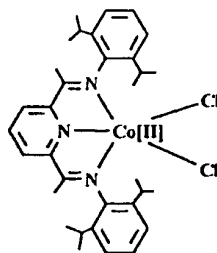
20 FeCl₂ (0.15 g; 1.18 mmol) was dissolved in hot n-butanol (20 ml) at 80°C. A suspension of 2,6-diacetylpyridinebis(2-tert.-butylanil) (0.5 g; 1.18 mmol) in n-butanol was added dropwise at 80°C. The reaction mixture turned blue. After stirring at 80°C for 15 minutes the reaction was allowed to cool down to room temperature. The reaction volume was reduced to a few ml and diethyl ether was added to precipitate the product as a blue powder, which was subsequently washed three times with 10 ml diethyl ether. The yield was 0.55 g (85 %). Analysis - Mass spectrum: m/z 551 [M]⁺, 516 [M-Cl]⁺, 426 [M-FeCl₂]⁺.

Example 55.1 - Preparation of 2,6-diacetylpyridinebis(2-methylanil)

30 The procedure was as for Example 4.1 except that 2-methyl aniline was used instead of 2-tertiarybutylaniline. The yield was Yield: 0.42 g (33%)
¹H NMR(CDCl₃): 8.48 (d, 2H, pyrH), 7.91 (t, 1H, pyrH), 7.28 (m, 4H, ArH), 7.10 (m, 2H, ArH), 6.75 (m, 2H, ArH), 2.42 (s, 6H, N=CCH₃), 2.20 (s, 6H, CH₃).

5.2 - Preparation of 2,6-diacetylpyridinebis(2-methylanil)FeCl₂

35 The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2-



FORMULA K

Examples 4 to 9 - Preparation of Iron ComplexesExample 44.1 - Preparation of 2,6-diacetylpyridinebis(2-tert.-butylanil)

To a solution of 2,6-diacetylpyridine (0.54 g; 3.31 mmol) in absolute ethanol (20 ml) was added 2-tertiarybutylaniline (1.23 g; 2.5 eq.). After the addition of 2 drops of acetic acid (glacial) the solution was refluxed overnight. Upon cooling to room temperature the product crystallised from ethanol. The product was filtered, washed with cold ethanol and dried in a vacuum oven (50°C) overnight. The yield was 1.07 g (76 %). Analysis $^1\text{H NMR}(\text{CDCl}_3)$: 8.43, 7.93, 7.44, 7.21, 7.09, 6.56 (m, 7H, ArH, pyrH), 2.43 (s, 6H, $\text{N}=\text{CCH}_3$), 1.39 (s, 18H, CCH_3).

4.2 - Preparation of 2,6-diacetylpyridinebis(2-tert.-butylanil) FeCl_2

FeCl_2 (0.15 g; 1.18 mmol) was dissolved in hot n-butanol (20 ml) at 80°C. A suspension of 2,6-diacetylpyridinebis(2-tert.-butylanil) (0.5 g; 1.18 mmol) in n-butanol was added dropwise at 80°C. The reaction mixture turned blue. After stirring at 80°C for 15 minutes the reaction was allowed to cool down to room temperature. The reaction volume was reduced to a few ml and diethyl ether was added to precipitate the product as a blue powder, which was subsequently washed three times with 10 ml diethyl ether. The yield was 0.55 g (85 %). Analysis - Mass spectrum: m/z 551 $[\text{M}]^+$, 516 $[\text{M}-\text{Cl}]^+$, 426 $[\text{M}-\text{FeCl}_2]^+$.

Example 55.1 - Preparation of 2,6-diacetylpyridinebis(2-methylanil)

The procedure was as for Example 4.1 except that 2-methyl aniline was used instead of 2-tertiarybutylaniline. The yield was Yield: 0.42 g (33%)

$^1\text{H NMR}(\text{CDCl}_3)$: 8.48 (d, 2H, pyrH), 7.91 (t, 1H, pyrH), 7.28 (m, 4H, ArH), 7.10 (m, 2H, ArH), 6.75 (m, 2H, ArH), 2.42 (s, 6H, $\text{N}=\text{CCH}_3$), 2.20 (s, 6H, CH_3).

5.2 - Preparation of 2,6-diacetylpyridinebis(2-methylanil) FeCl_2

The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2-

8.2 - Preparation of 2,6-diacetylpyridinebis(2,6-dimethylanil)FeCl₂

The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2,6-dimethylanil) was employed instead of 2,6-diacetylpyridinebis(2-tert.-butylanil). The yield was 78% of theoretical..

5 Mass spectrum: m/z 496 [M]⁺, 461 [M-Cl]⁺, 425 [M-Cl₂]⁺.

Example 9

9.1 Preparation of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)

The procedure was as for Example 4.1 except that 2,4,6-trimethyl aniline was used instead of 2-tertiarybutylaniline. The yield was 60% of theoretical.

10 ¹H NMR(CDCl₃): 8.50, 7.95, 6.94, (m, 7H, ArH, pyrH), 2.33 (s, 6H, N=CCH₃), 2.28 (s, 6H, CCH₃), 2.05 (s, 12H, CCH₃).

Mass spectrum: m/z 397 [M]⁺.

9.2 - Preparation of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂

15 The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2,4,6-trimethylanil) was employed instead of 2,6-diacetylpyridinebis(2-tert.-butylanil). The yield was 64% of theoretical.

Mass spectrum: m/z 523 [M]⁺, 488 [M-Cl]⁺, 453 [M-Cl₂]⁺.

Examples 4 to 9 - Polymerisation tests on Iron Complexes

20 The polymerisation tests were carried out using the following procedure. The catalysts (iron complexes) prepared in each of Examples 4 to 9 and cocatalyst (methylalumoxane - "MAO") was added to a Schlenk tube and dissolved in toluene (40 ml). The "MAO" was used as a 10 wt% solution in toluene (supplied by Aldrich, catalogue number: 40,459-4). The tube was purged with ethylene and the contents were mechanically stirred and maintained under 1 bar ethylene for the
25 duration of the polymerisation. The polymerisation tests were each commenced at room temperature (20°C). After half an hour the polymerisation was terminated by the addition of aqueous hydrogen chloride. The produced solid polyethylene was filtered off, washed with methanol and dried in a vacuum oven at 50°C. The toluene soluble fraction (PE tol. sol.) was isolated from the filtrate by separation of
30 the toluene layer from the aqueous layer, drying over MgSO₄ and removal of the toluene by distillation. GC/MS analysis showed that the toluene soluble fraction consists of oligomeric products.

8.2 - Preparation of 2,6-diacetylpyridinebis(2,6-dimethylanil)FeCl₂

The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2,6-dimethylanil) was employed instead of 2,6-diacetylpyridinebis(2-tert.-butylanil).

The yield was 78% of theoretical..

- 5 Mass spectrum: m/z 496 [M]⁺, 461 [M-Cl]⁺, 425 [M-Cl₂]⁺.

Example 99.1 Preparation of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)

The procedure was as for Example 4.1 except that 2,4,6-trimethyl aniline was used instead of 2-tertiarybutylaniline. The yield was 60% of theoretical.

- 10 ¹H NMR(CDCl₃): 8.50, 7.95, 6.94, (m, 7H, ArH, pyrH), 2.33 (s, 6H, N=CCH₃), 2.28 (s, 6H, CCH₃), 2.05 (s, 12H, CCH₃).

Mass spectrum: m/z 397 [M]⁺.

9.2 - Preparation of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂

- 15 The procedure was as for Example 4.2 except that 2,6-diacetylpyridinebis(2,4,6-trimethylanil) was employed instead of 2,6-diacetylpyridinebis(2-tert.-butylanil).

The yield was 64% of theoretical.

Mass spectrum: m/z 523 [M]⁺, 488 [M-Cl]⁺, 453 [M-Cl₂]⁺.

Examples 4 to 9 - Polymerisation tests on Iron Complexes

- 20 The polymerisation tests were carried out using the following procedure. The catalysts (iron complexes) prepared in each of Examples 4 to 9 and cocatalyst (methylalumoxane - "MAO") was added to a Schlenk tube and dissolved in toluene (40 ml). The "MAO" was used as a 10 wt% solution in toluene (supplied by Aldrich, catalogue number: 40,459-4). The tube was purged with ethylene and the contents were mechanically stirred and maintained under 1 bar ethylene for the
- 25 duration of the polymerisation. The polymerisation tests were each commenced at room temperature (20°C). After half an hour the polymerisation was terminated by the addition of aqueous hydrogen chloride. The produced solid polyethylene was filtered off, washed with methanol and dried in a vacuum oven at 50°C. The toluene soluble fraction (PE tol. sol.) was isolated from the filtrate by separation of
- 30 the toluene layer from the aqueous layer, drying over MgSO₄ and removal of the toluene by distillation. GC/MS analysis showed that the toluene soluble fraction consists of oligomeric products.

white powder (7.44 g, 75%)

Analysis - Mass spectrum (CI) 136 [M+H]⁺, 153 [M+NH₃]⁺

¹H NMR (250 Hz, CDCl₃) 10.17 (2H, s), 8.19 (2H, d, *J* = 8.4 Hz), 8.17 (1H, t, *J* = 8.4 Hz)

5 10.1 - Preparation of 2,6-dialdiminepyridinebis(2,6-dimethylanil)

To the 2,6-pyridinedicarboxaldehyde (0.80 g, 5.93 mmol), prepared as described above, in absolute ethanol (50 ml), was added redistilled 2,6-dimethylaniline (2.1 eq, 12.45 mmol, 1.5 ml) and glacial acetic acid (catalytic, 3 drops) and the resulting mixture was refluxed (24 h). Cooling and recrystallisation (absolute ethanol)

10 yielded a yellow powder, (1.654 g, 82%). Analysis Mass spectrum (CI) 342 [M+H]⁺

¹H NMR (250 Hz, CDCl₃) 8.43 (2H,s), 8.40(2H,d, *J* = 7.6 Hz), 8.00 (1H,t,7.6J), 7.10 (4H,d,*J* = 7.4 Hz), 6.99 (2H,t,*J* = 7.4 Hz), 2.20 (12H,s)

¹³C NMR (250 Hz, CDCl₃) 163.17, 154.45, 150.26, 137.32, 128.16, 126.77,

15 124.39, 122.68, 18.31

10.2 - Preparation of 2,6-dialdiminepyridinebis(2,6-dimethylanil)FeCl₂

To FeCl₂ (0.127 g, 1.0 mmol) dissolved in hot, dry, *n*-butanol (40 ml) at 80°C, a suspension of 2,6-dialdiminepyridinebis(2,6-dimethylanil) (0.341 g, 1.0 mmol, 1 eq) in hot, dry, *n*-butanol (10 ml) was added dropwise at 80°C. The reaction mixture turned green. After stirring for 15mins at 80°C the mixture was allowed to cool to room temperature and stirred for a further 12 h. The reaction solvent volume was reduced to approximately 1 ml and the reaction mixture was washed with diethyl ether (3x40 ml) to yield a light green powder (0.279 g, 60%).

Mass spectrum (FAB⁺) *m/z*: 467 [M]⁺, 432 [M-Cl]⁺

25 Example 11

11.1 - Preparation of 2,6-dialdiminepyridinebis(2,6-diethylanil)

To 2,6-pyridinedicarboxaldehyde (0.169 g, 1.25 mmol) prepared as described in Example 10.0 above, in absolute ethanol (25 ml), was added redistilled 2,6-diethylaniline (2.1 eq, 2.63 mmol, 0.36 ml) and glacial acetic acid (catalytic, 1 drop). The resulting mixture was refluxed (24 h). Cooling and recrystallisation (absolute ethanol) yielded a yellow powder, (0.371 g, 75%). Analysis - Mass spectrum (CI) 398 [M+H]⁺ ¹H NMR (250 Hz, CDCl₃) 8.44 (2H,s), 8.40 (2H,d,*J* = 7.6 Hz), 8.00 (1H,t,*J* = 7.6 Hz), 7.25 (6H,M), 2.55 (8H,q,*J* = 7.5 Hz), 1.61 (12H,t,*J* = 7.5 Hz)

35

white powder (7.44 g, 75%)

Analysis - Mass spectrum (CI) 136 [M+H]⁺, 153 [M+NH₃]⁺

¹H NMR (250 Hz, CDCl₃) 10.17 (2H, s), 8.19 (2H, d, *J* = 8.4 Hz), 8.17 (1H, t, *J* = 8.4 Hz)

5 10.1 - Preparation of 2,6-dialdiminepyridinebis(2,6-dimethylanil)

To the 2,6-pyridinedicarboxaldehyde (0.80 g, 5.93 mmol), prepared as described above, in absolute ethanol (50 ml), was added redistilled 2,6-dimethylaniline (2.1 eq, 12.45 mmol, 1.5 ml) and glacial acetic acid (catalytic, 3 drops) and the resulting mixture was refluxed (24 h). Cooling and recrystallisation (absolute ethanol)

10 yielded a yellow powder, (1.654 g, 82%). Analysis Mass spectrum (CI) 342 [M+H]⁺

¹H NMR (250 Hz, CDCl₃) 8.43 (2H,s), 8.40(2H,d, *J* = 7.6 Hz), 8.00 (1H,t,7.6J), 7.10 (4H,d,*J* = 7.4 Hz), 6.99 (2H,t,*J* = 7.4 Hz), 2.20 (12H,s)

¹³C NMR (250 Hz, CDCl₃) 163.17, 154.45, 150.26, 137.32, 128.16, 126.77,

15 124.39, 122.68, 18.31

10.2 - Preparation of 2,6-dialdiminepyridinebis(2,6-dimethylanil)FeCl₂

To FeCl₂ (0.127 g, 1.0 mmol) dissolved in hot, dry, *n*-butanol (40 ml) at 80°C, a suspension of 2,6-dialdiminepyridinebis(2,6-dimethylanil) (0.341 g, 1.0 mmol, 1 eq) in hot, dry, *n*-butanol (10 ml) was added dropwise at 80°C. The reaction

20 mixture turned green. After stirring for 15mins at 80°C the mixture was allowed to cool to room temperature and stirred for a further 12 h. The reaction solvent volume was reduced to approximately 1 ml and the reaction mixture was washed with diethyl ether (3x40 ml) to yield a light green powder (0.279 g, 60%).

Mass spectrum (FAB⁺) *m/z*: 467 [M]⁺, 432 [M-Cl]⁺

25 Example 11

11.1 - Preparation of 2,6-dialdiminepyridinebis(2,6-diethylanil)

To 2,6-pyridinedicarboxaldehyde (0.169 g, 1.25 mmol) prepared as described in Example 10.0 above, in absolute ethanol (25 ml), was added redistilled 2,6-

diethylaniline (2.1 eq, 2.63 mmol, 0.36 ml) and glacial acetic acid (catalytic, 1 drop). The resulting mixture was refluxed (24 h). Cooling and recrystallisation

30 (absolute ethanol) yielded a yellow powder, (0.371 g, 75%). Analysis - Mass spectrum (CI) 398 [M+H]⁺ ¹H NMR (250 Hz, CDCl₃) 8.44 (2H,s), 8.40 (2H,d,*J* = 7.6 Hz), 8.00 (1H,t,*J* = 7.6 Hz), 7.25 (6H,M), 2.55 (8H,q,*J* = 7.5 Hz), 1.61 (12H,t,*J* = 7.5 Hz)

35

(2.1 eq, 10.10 mmol, 1.448 g) and glacial acetic acid (catalytic, 1 drop). The resulting mixture was refluxed (24 h). Cooling and recrystallisation (absolute ethanol) yielded a yellow powder, (1.48 g, 80%). Analysis - Mass spectrum (EI) 385 [M]⁺

5 13.2 - Preparation of 2,6-dialdiminepyridinebis(1-naphthyl)FeCl₂

To FeCl₂ (0.20 g, 1.57 mmol) dissolved in hot, dry *n*-butanol (80 ml) at 80°C, a suspension 2,6-dialdiminepyridinebis(1-naphthyl) (0.610 g, 1.57 mmol, 1 eq) in hot, dry, *n*-butanol (25 ml) was added dropwise at 80°C. The reaction mixture turned green. After stirring for 15 mins at 80°C the mixture was allowed to cool to
10 room temperature and stirred for a further 12 h. The reaction solvent volume was reduced to approximately 1 ml and the reaction mixture was washed, with diethyl ether (3x40 ml) to yield a green powder, (0.57 g, 71%). Analysis - Mass spectrum (FAB⁺) *m/z*: 511 [M]⁺, 476 [M-Cl]⁺, 441 [M-Cl₂]⁺, 386 [M-FeCl₂]⁺

Examples 10 to 13 - Polymerisation Tests

15 The iron complexes prepared in Examples 10 to 13 were tested in polymerisation of ethylene under the following standard conditions. To the iron complex (0.01 mmol), dissolved in toluene (40 ml, dry) in a Schlenk tube, the cocatalyst (methylaluminoxane - 'MAO') was added (0.065 ml, 10 wt% in toluene, 100 eq (Fe:Al = 1:100)) to produce an orange solution. The Schlenk tube was placed in a
20 water bath, purged with ethylene and the contents magnetically stirred and maintained under 1 bar ethylene for the duration of the polymerisation. After 30 minutes the polymerisation was terminated by the addition of aqueous hydrogen chloride. The insoluble, solid, polyethylene was recovered by filtration, washed with methanol (50 ml) and dried (vacuum oven at 50 °C). The toluene solution was
25 dried over MgSO₄, and the solvent removed under vacuum to yield traces of waxy material. GC-MS of the toluene solution showed the waxy material to consist of α-olefins (vinyl terminated oligomeric hydrocarbons). The results of the polymerisation tests are shown in the following Table.

30

35

TABLE					
Iron complex Example No.	Cocatalyst /eq (note 1)	Solid PE/g	Soluble PE (note 2)	MW solid PE	Activity / g mmol ⁻¹ bar ⁻¹ h ⁻¹
10	MAO	3.618	0.085	15000	740
11	MAO	2.984	0.261		649
12	MAO	4.803	0.038	33000	968
13	MAO	0.450	0.601	900	210

Notes on the Table

- 1) MAO obtained from the Aldrich Chemical Co
- 2) Recovered from the reaction medium. In Example 13 the Mw of the soluble PE (polyethylene) was 300.

15 Examples 14 to 25

These Examples are a series of tests wherein ethylene or ethylene/1-hexene is polymerised under 10 bars ethylene pressure using the catalysts of the present invention under "slurry" polymerisation conditions.

Catalyst Preparation

- 20 The transition metal complexes employed as catalyst in Examples 14 to 25 were as follows:

In Examples 14 and 15 the complex was 2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂ prepared as described in Example 1 (Formula D compound).

- 25 In Examples 16 to 20 the complex was 2,6-diacetylpyridinebis(2,6-dimethylanil)FeCl₂ prepared as described in Example 8.

In Example 21 the complex was 2,6-diacetylpyridinebis(2,4-dimethylanil)FeCl₂ prepared as described in Example 7.

In Examples 22 to 24 the complex was

- 30 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ prepared as described in Example 9.

In Example 25 the complex was 2,6-diacetylpyridinebis(2,6-diisopropylanil)CoCl₂ prepared as described in Example 3 (Formula K).

Catalyst activation

- 35 The transition metal complex was dissolved in toluene (previously dried over sodium metal) under a nitrogen atmosphere and there was added a solution of

activator (cocatalyst) at ambient temperature. The mixture was stirred at room temperature then an aliquot transferred to the injection unit of a polymerisation reactor. The quantities of reagents employed in the catalyst activation are set out in the following Table. All operations were conducted under a nitrogen

- 5 atmosphere unless specified. "MAO" is methyl aluminoxane (1.78M in toluene supplied by Witco). "MMAO" is modified methyl aluminoxane (10%w/w in heptane - supplied by Witco) were used as purchased. Triisobutylaluminium ($\text{Al}(\text{iBu})_3$) as a 1M solution in toluene was supplied by Aldrich.

10

TABLE								
Ex. No.	Metal Complex (mg)	[Metal] (μmol s)	Cocatalyst		[Al] mmols	[M]:[Al]	Toluene (ml)	Solution Molarity (M)
			type	(ml)				
14	3	5	MAO	2.78	5	1:1000	20	0.0025
15	3	5	MAO	2.78	5	1:1000	20	0.0025
16	1.5	3	MAO	1.70	3	1:1000	10	0.0025
17	1.5	3	MMAO	3.93	3	1:1000	10	0.0025
18	1.5	3	MAO	1.70	3	1:1000	50	0.0006
19	1.5	3	MAO	1.70	3	1:1000	10	0.0025
20	1.5	3	MAO	0.17	3	1:1000	10	0.0025
21	1.5	3	MAO	1.70	3	1:1000	10	0.0025
22	3	6	MAO	3.22	6	1:1000	20	0.003
23	1.5	3	MAO	1.61	3	1:1000	10	0.003
24	3	6	MAO	0.32	0.3	1:100	20	0.003
25	3	5	MAO	2.78	5	1:1000	20	0.0025

20

25 Polymerisation Tests

The reagents used in the polymerisation tests were Ethylene Grade 3.5 (supplied by Air Products), hexene (supplied by Aldrich) distilled over sodium/nitrogen and triisobutylaluminium (1M in hexanes, supplied by Aldrich).

Polymerisation of Ethylene

- 30 A 1 litre reactor was baked out under a nitrogen flow for at least 1 hour at $>85^\circ\text{C}$. The reactor was then cooled to 50°C . Isobutane (0.5 litre) and triisobutylaluminium were then added and the reactor was boxed in nitrogen. The alkyl aluminium was allowed to scavenge for poisons in the reactor for at least 1 hour. Ethylene was introduced into the reactor until a predetermined over-
- 35 pressure was achieved then the catalyst solution was injected under nitrogen. The

reactor pressure was maintained constant throughout the polymerisation run by computer controlled addition of additional ethylene. The polymerisation time was 1 hour. Upon termination of the run the reactor contents were isolated, washed with acidified methanol (50ml HCl/2.5l methanol) and water/ethanol (4:1 v/v) and dried under vacuum, at 40°C, for 16 hours.

Copolymerisation of Ethylene/1-Hexene (Example 19)

A 1 litre reactor was baked out under a nitrogen flow for at least 1 hour at >85°C. The reactor was then cooled to 50°C, isobutane (0.5 litre), 1-hexene and triisobutylaluminium were then added and the reactor was boxed in nitrogen. The alkyl aluminium was allowed to scavenge for poisons in the reactor for at least 1 hour. Ethylene was introduced into the reactor until a predetermined over-pressure was achieved then the catalyst solution was injected under nitrogen. The reactor pressure was maintained constant throughout the polymerisation run by computer controlled addition of ethylene. The polymerisation time was 40 minutes. Upon termination of the run the reactor contents were isolated, washed with acidified methanol (50ml HCl/2.5l methanol) and water/ethanol (4:1 v/v) and dried under vacuum, at 40°C, for 16 hours.

Data from the polymerisation tests are set out below in the Table

TABLE								
Ex. No.	[metal] (μmols)	metal/alum-inoxane Ratio	C ₂ H ₄ Bar	Al(iBu) ₃ (ml)	polymer-isation Temp. (°K)	polymer (g)	activity (g/mmol M/l/v)	ppm
14	0.5	1:1000	10	3	323	26.9	5430	1.03
15	0.5	1:1000	10	3	298	45.0	9090	0.61
16	0.6	1:1000	10	3	323	56.5	9340	0.60
17	0.6	1:1000	10	3	323	57.4	9510	0.59
18	0.12	1:1000	10	3	323	3.3	2540	2.2
19#	0.6	1:1000	10#	3	323	67.6	16690	0.50
20	0.6	1:1000	10	3	323	74.5	12310	0.45
21	0.6	1:1000	10	3	323	7.8	1280	4.36
22	0.6	1:1000	10	3	323	63.1	11020	0.51
23	0.12	1:1000	10	3	323	55.7	48690	0.11
24	0.6	1:100	2	2	323	18.21	15150	1.84
25	0.8	1:1000	10	3	323	3.7	450	13.1

5

Notes on the Table

- 10 # Example 19 illustrated copolymerisation of ethylene with 1-hexene. 1-Hexene (50ml) was included in the polymerisation. The remaining Examples were all homopolymerisation of ethylene.
- “ppm” is defined as parts by weight of transition metal per million parts by weight of polymer.
- 15 Molecular weight data of the polymers obtained from Examples 14 to 25 are set out in the Table below.

20

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TABLE				
Ex. No.	Mw	Mn	Mpeak	PD
14	611000	64000	246000	9.5
15	857000	212000	451000	4.0
16	242000	9600	16000	25.3
17	278000	5700	1300	48.7
18	366000	50000	102000	7.3
19	377000	6500	43000	57.7
21	470	360	370	1.3
25	14000	4200	12000	3.3

Examples 26 and 27Gas Phase Polymerisation Tests with Supported Catalysts

Examples 26 and 27 illustrate the use of the catalysts of the present invention supported on silica support material. Example 26 employs 2,6-

- 5 diacetylpyridinebis(2,6-diisopropylanil)FeCl₂, and Example 27 employs 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ as the transition metal complex compound..

Example 26Preparation of the supported catalyst

- 10 2,6-Diacetylpyridinebis(2,6-diisopropylanil)FeCl₂ was prepared as described in Example 1.

Silica (1.03g ES70, supplied by Crosfield), which had been heated under flowing nitrogen at 700°C, was placed in a Schlenk tube, and toluene (10ml) was added.

- 15 The mixture was heated to 50°C. To a solution of 2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂ (0.036g) in toluene (10ml) was added methylaluminoxane (5ml, 1.78M in toluene, supplied by Witco). This mixture was heated at 50°C and then transferred to the silica/toluene mixture. The silica/MAO/toluene mixture was maintained at 50°C, with regular stirring, for 1 hour before the toluene was removed, at 65°C, under vacuum to yield a free flowing powder.

- 20 Example 27

Preparation of the supported catalyst

2,6-Diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ was prepared as described in Example 9. Silica (1.38g ES70, supplied by Crosfield), which had been heated under flowing nitrogen at 700°C, was placed in a Schlenk tube and toluene (10ml)

- 25 was added.

To a solution of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ (0.041g) in toluene (10ml) was added methylaluminoxane (13.2ml, 1.78M in toluene, supplied by Witco). This mixture was heated at 40°C for 30 minutes to dissolve as much of the iron complex as possible. The solution was then transferred to the

- 30 silica/toluene. The silica/MAO/toluene mixture was maintained at 40°C, with regular stirring, for 30 minutes before the toluene was removed, at 40°C, under vacuum to yield a free flowing powder. Analysis of the solid gave 16.9 %w/w Al and 0.144 %w/w Fe.

Polymerisation Tests - Examples 26 and 27

- 35 The reagents used in the polymerisation tests were: hydrogen Grade 6.0 (supplied

by Air Products): ethylene Grade 3.5 (supplied by Air Products): hexene (supplied by Aldrich) distilled over sodium/nitrogen: dried pentane (supplied by Aldrich): methylaluminium (2M in hexanes, supplied by Aldrich): and triisobutylaluminium (1M in hexanes, supplied by Aldrich).

- 5 A 3 litre reactor was baked out under flowing nitrogen for at least 1 hour at 77 - 85°C before powdered sodium chloride (300g, predried under vacuum, 160°C, >4 hours) was added. The sodium chloride was used as a fluidisable/stirrabable start-up charge powder for the gas phase polymerisation. Trimethyl aluminium (3ml, 2M in hexanes) was added to the reactor and was boxed in nitrogen. The alkyl aluminium
- 10 was allowed to scavenge for poisons in the reactor for between ½ - 1 hour before being vented using 4 x 4 bar nitrogen purges. The gas phase composition to be used for the polymerisation was introduced into the reactor and preheated to 77°C prior to injection of the catalyst composition. The catalyst (0.18 - 0.22g) was injected under nitrogen and the temperature then adjusted to 80°C. The ratio of
- 15 hexene and/or hydrogen to ethylene during the polymerisation was kept constant by monitoring the gas phase composition by mass spectrometer and adjusting the balance as required. The polymerisation tests were allowed to continue for between 1 to 2 hours before being terminated by purging the reactants from the reactor with nitrogen and reducing the temperature to < 30°C. The produced
- 20 polymer was washed with water to remove the sodium chloride, then with acidified methanol (50ml HCl/2.5L methanol) and finally with water/ethanol (4:1 v/v). The polymer was dried under vacuum, at 40°C, for 16 hours. Several Runs, using a variety of operating conditions were carried out with each of the catalysts of Examples 26 and 27. All the polymerisation tests were carried out at a
- 25 polymerisation temperature of 80°C and at an ethylene pressure of 8 bars. The polymerisation conditions are set out in the following Table

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TABLE								
Ex/ Run	Metal (%w/w)	MAO/ Metal Ratio	other co- catalyst/ (mmols)	H ₂ (bar)	hexene (bar)	pentane (bar)	Run time (min)	Activity g/mmol M/h/b
26.1	0.21	150	****	****	****	****	75	77
26.2	0.21	150	****	****	0.195	****	90	77
26.3	0.21	150	TMA /6	****	****	****	60	149
26.4	0.21	150	TMA /6	0.75	****	****	60	318
27.1	0.144	300	****	****	****	****	60	611
27.2	0.144	300	TMA /6	0.5	****	****	60	832
27.3	0.144	300	TMA /6	0.5	0.2	****	60	1054
27.4	0.144	300	TMA /6	0.5	****	2.4	60	1800
27.5	0.144	300	TiBA /3	****	****	****	60	713
27.6	0.144	300	****	3	****	****	60	501
27.7	0.144	300	****	****	0.86	****	60	418

Molecular weight data on the polymer products is set out in the Table below.

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25

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Run	Catalyst	Mw	Mn	Mpeak	Polydispersity
26.2	Ex 26	892000	106000	332000	8.4
26.3	Ex 26	278000	8400	95000	33.0
26.4	Ex 26	195000	7200	43000	27.0
27.1	Ex 27	324000	9300	134000	34.6
27.2	Ex 27	223000	18000	42000	12.3
27.3	Ex 27	77000	6000	21000	12.8
27.4	Ex 27	154000	5700	28000	26.9
27.5	Ex 27	207000	4800	86000	43.1
27.6	Ex 27	69000	5400	14000	12.7
27.7	Ex 27	127000	14000	51000	9.3

The polymer obtained in Example 27.7 contained short chain branching (SCB) corresponding to 1.6 n-butyl branches/1000C.

Example 2828.0 - Preparation of 2,6-dialdiminepyridinebis(2,4,6-trimethylanil)

- 2,6-dimethanolpyridine (6.53 g, 0.048 mol) in absolute ethanol (50 ml), 2,4,6-trimethylaniline (2.5 equivalents, 17.0 ml, 0.12 mol) and glacial acetic acid (3 drops) were mixed together and refluxed for 24 hours. On cooling the mixture, yellow crystals of 2,6-dialdiminepyridinebis(2,4,6-trimethylanil) were separated out (14.28g, 80% yield).

Analysis of the crystalline product by ^1H NMR: (250 Hz) 8.42(s, 2H), 8.40 (s, 2H), 8.0(t, $^3\text{J}(\text{HH})$ 8, JH), 7.0(s, 4H), 2.33(s, 6H), 2.19(s, 12H).

- 10 Mass spectrum: m / z 369 $[\text{M}]^+$.

28.1 - Preparation of 2,6-dialdiminepyridinebis(2,4,6-trimethylanil)FeCl₃

(Formula G) - see below

FeCl₃ (0.10 g; 0.615 mmol) was dissolved in MeCN (25 ml) at room temperature and 2,6-dialdiminepyridinebis(2,4,6-trimethylanil) (0.227 g, 0.615 mmol) added.

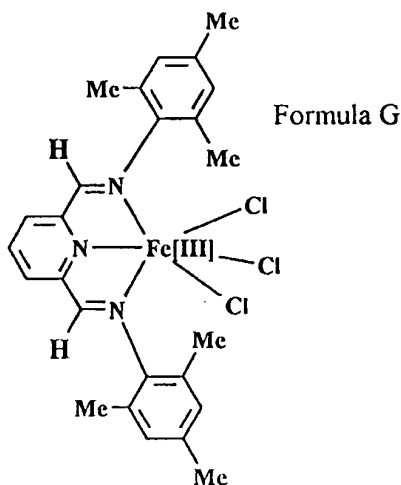
- 15 After 24 hours stirring at room temperature a red precipitate of 2,6-dialdiminepyridinebis(2,4,6-trimethylanil)FeCl₃ (0.192 g, 60%) was collected and dried. Analysis of the product: Mass spectrum: m / z 531 $[\text{M}]^+$, 496 $[\text{M}-\text{Cl}]^+$, 462 $[\text{M}-2\text{Cl}]^+$.

28.2 - Polymerisation Test

- 20 The 2,6-dialdiminepyridinebis(2,4,6-trimethylanil)FeCl₃ (0.02 mmol) prepared as above was dissolved in toluene (40 ml) in a Schlenck tube, to give a red solution and the cocatalyst (methylalumoxane), MAO) (8.0 mmol, 400 equiv.) introduced (formation of a orange solution was observed). The MAO was supplied by Aldrich (catalogue number: 40,459-4). The tube was purged with ethylene and the contents stirred under 1 bar ethylene for the duration of the polymerisation. The run was stopped after 0.5 hour by adding aqueous HCl solution. Solid polyethylene (1.5g) was collected by filtration, washed with methanol and dried in a vacuum oven at 50°C. Polyethylene soluble in the toluene was isolated from the filtrate by separation of the toluene layer from the aqueous layer, drying over
- 30 MgSO₄ and removal of the toluene by distillation. The weight of toluene-soluble polyethylene obtained was 2.46g. The catalyst activity (based on the total weight of polyethylene obtained) was 396 g mmol⁻¹h⁻¹bar⁻¹.

5

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Example 29

15 Preparation of a catalyst from 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂
 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ prepared as described in Example
 9. To 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ (17mg, 0.03mmol)
 dissolved in Et₂O (20ml), at -78°C, was added dropwise a solution of
 trimethylsilylmethyl magnesium chloride(0.164mmol, 1M solution in Et₂O). The
 20 solution was stirred for 10 minutes then allowed to warm to 0°C and stir for a
 further 5 minutes. The reaction solvent was removed under reduced pressure. To
 the iron complex was added trityltetra(pentafluorophenyl)borate(151mg,
 0.164mmol) and toluene (20ml, dried) yielding a red solution. The Schlenk tube
 was purged with ethylene and the contents magnetically stirred and maintained
 25 under 1 bar ethylene for the duration of the polymerisation. After 60 minutes the
 polymerisation was terminated by addition of acidified methanol (50ml HCl/2.5L
 methanol). The insoluble, solid, polyethylene was recovered by filtration, washed
 with methanol/water (1:4 v/v) and dried (vacuum oven at 40°C). Yield of solid
 polyethylene 0.90g, a polymerisation activity of 28 gmmol⁻¹bar⁻¹h⁻¹.

30 Reagents used in Example 29 were as follows:

Trimethylsilylmethyl magnesium chloride(purchased from Aldrich as a 1M solution
 in Et₂O)

Trityltetra(pentafluorophenyl)borate (purchased from Boulder)

Diethylether (purchased from Aldrich, dried over sodium)Toluene (purchased from

35 Aldrich, dried over sodium)

Examples 30 and 31

In these Examples, iron (II) complexes comprising tridentate pyridine-hydrazone ligands in accordance with the present invention were synthesised and tested as olefin polymerisation catalysts.

5 30.1 - Preparation of 2,6-bis(1-methyl,1-phenylhydrazone)pyridine

2,6-diacetylpyridine (5.0 g, 30.6 mmol) [Aldrich Chemicals] and 1-methyl,1-phenylhydrazine (7.21ml, 61.3 mmol) [Aldrich Chemicals] in absolute ethanol were stirred together and then heated to reflux for 12hours. On reducing the volume of the solution by evaporating some of the ethanol and cooling to -20°C, yellow
10 needles of 2,6-bis(1-methyl,1-phenylhydrazone)pyridine were obtained which were filtered off. Yield *ca* 90%. Mass spectrum:*m/z*. M^+ 372. Analysis by ^1H NMR (300MHz, CDCl_3 , 298K) δ : 2.52 (s, 6H, $\text{CH}_3\text{C}=\text{N}$), 3.32 (s, 6H, $\text{CH}_3\text{-N}$), 6.95-8.31 (multiplets, 13H, aryls).

30.2 - Preparation of 2,6-bis(1-methyl,1-phenylhydrazone)pyridine. FeCl_2 complex
15 $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ (0.21 g; 1.06 mmol) and 2,6-bis(1-methyl,1-phenylhydrazone)pyridine (0.39 g; 1.06 mmol) were stirred together in anhydrous n-butanol (10 ml) and heated at 80°C for 2 hours. The reaction was then allowed to cool down to room temperature. Removal of volatiles in-vacuo, extraction into warm MeCN (30ml) and cooling (-20°C) afforded the desired iron complex (Formula L below) as large
20 brown needles. Yield *ca* 85%.

25 31.1 - Preparation of 2,6-bis(1,1-diphenylhydrazone)pyridine

This compound was prepared in analogous manner to that outlined in Example 30.1 using 2,6-diacetylpyridine (1.0 g, 6.13mol) and 1,1-diphenylhydrazine hydrochloride (2.7g, 12.3 mmol) [Aldrich Chemicals]. Yield *ca* 85%. Analysis by
25 ^1H NMR (300MHz, CDCl_3 , 298K) δ : 2.12 (s, 6H, $\text{CH}_3\text{C}=\text{N}$), 7.09 - 8.35 (multiplets, 23H, aryls).

30 31.2 - Preparation of 2,6-bis(1,1-diphenylhydrazone)pyridine. FeCl_2 complex

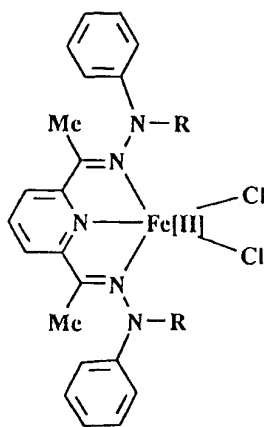
This complex (see Formula M below) was prepared by an analogous manner to that outlined in Example 30.2 from $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$ (0.5 g, 2.51 mmol) and 2,6-
30 bis(1,1-diphenylhydrazone)pyridine (1.19 g, 2.52 mmol). Yield *ca* 70%
Mass spectrum:*m/z* M^+ - C1 586.

30.3 and 30.4 - Polymerisation Tests

The iron complexes prepared in Examples 30.2 and 31.2 were tested in polymerisation of ethylene under the following standard conditions. To the iron
35 complex, dissolved in toluene (40ml, dried over sodium wire) in a Schlenk tube,

the cocatalyst (methylaluminoxane - "MAO") was added. The "MAO" was purchased from Witco as a 1.78M solution in toluene. The Schlenk tube was purged with ethylene and the contents magnetically stirred and maintained under 1 bar ethylene for the duration of the polymerisation. After 60 minutes the polymerisation was terminated by addition of acidified methanol (50ml HCl/2.5 litres methanol). The insoluble, solid, polyethylene was recovered by filtration, washed with methanol/water (1:4 v/v) and dried (vacuum oven at 50°C). For Example 30, the produced polyethylene solution was dried over MgSO₄ and the solvent removed under vacuum to yield traces of a waxy material. The results of the polymerisation tests are shown in the following Table

TABLE						
Ex.	Catalyst /mmol	Cocatalyst /mmol	Fe:Al Ratio	Solid PE/g	Sol. PE	Activity /gmmol ⁻¹ bar ⁻¹ h ⁻¹
30	0.02	8	1:400	-	0.04	2
31	0.008	3.2	1:400	1.01	-	130



Formula L
R = Methyl

Formula M
R = Phenyl

Example 32

32.1 - Preparation of a supported Ziegler catalyst component

Silica (20 kg), grade ES 70 supplied by Crosfield, which had been dried at 800°C for 5 hours in flowing nitrogen, was slurried in hexane (110 litres) and hexamethyldisilazane (30 moles), supplied by Fluka, was added with stirring at 50°C. Dry hexane (120 litres) was added with stirring, the solid allowed to settle,

the supernatant liquid removed by decantation and further dry hexane (130 litres) was added with stirring. The hexane washing was repeated a further 3 times. Dibutylmagnesium (30 moles), supplied by FMC, was added and stirred for 1 hour at 50°C. Tertiary butyl chloride (60 moles) was added and stirred for 1 hour at 50°C. To this slurry was added an equimolar mixture of titanium tetrachloride (3 moles), and titanium tetra-n-propoxide (3 moles) with stirring at 50°C for 2 hours, followed by 5 washings with dry hexane (130 litres). The slurry was dried under a flowing nitrogen stream to give a solid, silica supported Ziegler catalyst component.

10 32.2 - Preparation of a mixed catalyst containing a Ziegler component and a transition metal compound of the Present Invention

A solution of methylaluminoxane ("MAO", 10.2 mmol) as a 10% wt solution in toluene, supplied by Witco, was added to a suspension of 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂ (0.07mmol in 5ml dry toluene), prepared as in Example 9, and the mixture shaken for 5 minutes. This solution was then added to 2.0g of the silica supported Ziegler catalyst prepared above (Example 32.1), the mixture shaken for 2 hours at 20°C and then the solvent removed under reduced pressure at 20°C to yield the mixed catalyst as a free flowing powder.

20 32.3 - Polymerisation of ethylene/hexene mixture using the mixed catalyst

A 3 litre reactor equipped with a helical stirrer was heated to 95°C for 1 hour with dry nitrogen flowing through. The temperature was reduced to 50°C and dry sodium chloride (300g) was then added with trimethylaluminium (TMA) solution (2ml of 2 molar TMA in hexane) and the reactor heated at 85°C for 2 hours. The reactor was purged with nitrogen, cooled to 50°C and TMA solution (3ml of 2 molar TMA in hexane) added. The temperature was raised to 77°C and hydrogen (0.5 bar) and ethylene (8 bar) added prior to the addition of 1-hexene (2.6ml). Reaction was started by injection into the reactor of the mixed catalyst (0.20g) prepared above. The temperature was maintained at 80°C and ethylene added to maintain constant pressure. The gas phase was monitored by a mass spectrometer and hydrogen and 1-hexene added as necessary to maintain constant gas phase concentrations of these components. The polymerisation was carried out for 90 minutes. The polymer was washed with water to remove the sodium chloride, then with acidified methanol (50 ml HCl/2.5 litres methanol) and finally with water/ethanol (4:1 v/v). The polymer was dried under vacuum, at 40°C for 16

hours. 111g of dried polymer was produced. The polymer had a broad molecular weight distribution (as determined by gel permeation chromatography. The polydispersity (M_w/M_n) was 28.5.

Example 33

5 33.1 - Pre-impregnation of support with activator compound

All the following operations were conducted under a nitrogen atmosphere unless stated. Silica (Crosfield grade ES70X) was heated under flowing nitrogen at 250° for 16 hours. A sample of this silica (2.5g) was placed in a Schlenk tube and had 12.1 ml of 1.78M methylaluminoxane, MAO (supplied by Witco) added to it to
10 form a slurry. The slurry was heated for 4 hours at 50°C before being left for 10 days at room temperature. The supernatant liquid above the silica was removed and the silica/MAO washed three times with toluene (3 X 10ml) at room temperature, removing the supernatant solution each time.

33.2 - Supporting the Catalyst

15 (2,6-diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride (0.101g) (prepared as described in Example 9) was slurried in toluene (20ml), at room temperature, and added to the silica/MAO. The mixture was occasionally shaken over a 1 hour period. The supernatant solution was removed and the silica/MAO/Fe complex was washed with toluene until the filtrate was colourless. The solid was dried under
20 vacuum at 50°C.

33.3 - Gas Phase Polymerisation of ethylene

A 3 litre reactor was baked out under flowing nitrogen for at least 1 hour at 77°C before sodium chloride (300g, <1mm diameter particles, predried under vacuum, 160°C, >4 hours) was added. The sodium chloride was employed merely as a
25 standard "charge powder" for the gas phase polymerisation reactor. Trimethyl aluminium (3ml, 2M in hexanes, supplied by Aldrich) was added to the reactor which was then closed. The alkyl aluminium was allowed to scavenge for poisons in the reactor for ½ hour before being vented by successive pressurising and purging the reactor with 4 bar of nitrogen. Ethylene (Grade 3.5, supplied by Air
30 Products) was added to the reactor to give a pressure of 8 bar, at 77°C, prior to catalyst injection. The supported catalyst (0.215g) prepared as described in Example 33.2 was injected into the reactor under nitrogen and the temperature then adjusted to 80°C. The polymerisation was allowed to continue for 5 hours before being terminated by purging the ethylene from the reactor, using nitrogen,
35 and reducing the temperature to below 30°C. The polymer was washed with water

to remove the sodium chloride, then with acidified methanol (50ml HCl/2.5 litres methanol) and finally with water/ethanol (4:1 v/v). The polymer was dried under vacuum, at 40°C, for 16 hours. 161 g of dried polymer was produced.

Example 34 - Polymerisation Catalyst modified with a neutral Lewis Base

- 5 The 2,6-diacetylpyridinebis(2,6-diisopropylanil)FeCl₂ complex prepared in Example 1 was tested in polymerisation of ethylene under the following standard conditions. To the iron complex (8μmol) dissolved in dried toluene (10ml) in a Schlenk tube, a solution of N,N-dimethylaniline in toluene (10ml) then the cocatalyst (methylaluminoxane - 'MAO', 8mmol of a 1.78M MAO solution in
- 10 toluene, supplied by Witco, reference AL 5100/10T) was added. The contents of the Schlenk were magnetically stirred and maintained under 1 bar ethylene for the duration of the polymerisation. After 60 minutes the produced polymer was washed with acidified methanol (50ml HCl/2.5 litres methanol) and finally with water/ethanol (4:1 v/v). The polymer was dried under reduced pressure, at 40°C,
- 15 for 16 hours. Several runs, using a variety of operating conditions were carried out and the polymerisation conditions are set out in the following Table.

20

Run	DMA μmol	Fe/DMA Ratio	Activity	Mw	Mn	Mw/Mn
34.1	8	1	890	790	660	1.2
34.2	80	10	617	1000	720	1.4
34.3	800	100	892	63000	4825	20.7
C	-	-	1030	89000	1100	77.8

25 Notes on the Table

DMA is N,N-dimethylaniline

Activity is expressed as g polymer mmol⁻¹ transition metal h⁻¹bar⁻¹

C = Comparative Test using no DMA

30 Examples 35 to 38

These illustrate the preparation of supported catalysts in accordance with the present invention and their use in the polymerisation of ethylene under "slurry" polymerisation conditions.

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Example 35

35.1 - Preparation of 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride supported on MAO/silica

Silica support material (grade ES70X supplied by Crosfield) was heated under
5 flowing nitrogen at 250°C for 16 hours. A sample of this silica was placed in a
Schlenk tube and 12.1 ml of 1.78M methylaluminoxane ("MAO" supplied by
Witco) was added to it to form a slurry. The slurry was heated for 4 hours at 50°C
before being left for 10 days at room temperature. The supernatant liquid above
the silica was then removed and the silica/MAO washed 3 times with toluene (10
10 ml) at room temperature, removing the supernatant solution each time. 2,6-
diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride complex (0.101g) was
slurried in toluene (20 ml), at room temperature, and added to the silica/MAO.
The mixture was occasionally shaken over a 1 hour period. The supernatant
solution was removed and the produced silica-supported MAO/Fe complex washed
15 with toluene until the initial washings, which were light orange in colour, became
clear and free from colour. The produced silica-supported catalyst solid was dried
under vacuum at 50°C.

35.2 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen (2 litres/min) for 1 hour at
20 95°C. The reactor was cooled to 40°C and 500 ml of isobutane added. The
temperature of the reactor was raised to 80°C and ethylene admitted to the reactor
to give a partial pressure of 10 bar. The supported catalyst prepared in 35.1 above
(0.201g, slurried in 10 ml of toluene) was injected under nitrogen and the pressure
increase in the reactor taken into account during control of the reactor pressure
25 during the polymerisation test. The test was terminated after 1 hour and the
polymer dried under vacuum at 40°C. 5.9g of polymer was recovered. Analysis of
the polymer by GPC indicated Mw and Mn to be 124000 and 15000 respectively.

35.3 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen for 3 hours at 80°C. The
30 reactor was cooled to less than 30°C and 500 ml of isobutane added. Trimethyl
aluminium (3 ml of 2M in hexanes) was added to the reactor and this was then
heated to 80°C. The pressure in the reactor increased to 13.8 bar and then ethylene
was admitted to give a total pressure of 23.8 bar. The supported catalyst prepared
in 35.1 above (0.201g of the supported catalyst solid in toluene slurry) was injected
35 into the reactor under nitrogen causing the reactor pressure to increase to 25.4 bar.

The catalyst activity was slightly too high for the ethylene inlet flow to keep the pressure constant and this was therefore allowed to fall to 23.2 bar. The ethylene pressure present in the reactor for the majority of the polymerisation was estimated to be 7.8 bar. The test was terminated after 1.75 hours and the polymer washed
5 with methanol/HCl (2.5 litres/50 ml), then water/ethanol (4:1 v/v) and dried under vacuum at 40°C. 166g of dry polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 182000 and 11000 respectively.

Example 36

36.1 - Preparation of 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride supported on MAO/silica

A portion (about 1-1.5g) of the supported catalyst prepared in Example 35.1 was washed with 5 x 10 ml aliquots of toluene at 100°C. The initial washings had a deep orange colour and this coloration became less with each subsequent washing until the final washing was clear of colour. The solid was dried under vacuum at
15 100°C to provide free-flowing solid supported catalyst.

36.2 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 75°C. Trimethyl aluminium (3 ml of 2M in hexanes) was added to the reactor which was then cooled to 50°C. Isobutane (500 ml) was added to the reactor and the temperature
20 increased to 76°C. The pressure in the reactor increased to 13 bar. Ethylene was admitted to the reactor to give 21 bar total pressure (8 bar ethylene). The supported catalyst prepared in 26.1 above (0.11g in toluene slurry) was injected into the reactor and the pressure increase taken into account during control of the reactor pressure during the test. The temperature was increased to 80°C. After 1
25 hour a further aliquot of the same catalyst was injected (0.22g in hexane slurry) and the test continued for a further 3.5 hours. 25g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 343000 and 35000 respectively.

Example 37

37.1 - Preparation of 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride supported on MAO/silica

Methyl aluminoxane (24 ml of 1.78M in toluene, supplied by Witco) was added to silica (5g of grade ES70X supplied by Crosfield) which had been heated under flowing nitrogen at 250°C. The silica/MAO was heated at 80°C for 1 hour before
35 being washed toluene (5 x 10 ml aliquots). Half of the produced silica/MAO

slurry, cooled to room temperature, was used for the next stage of the catalyst preparation (the other half was put aside for use in Example 38).
2,6-Diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride (73 mg) was slurried in toluene and transferred to the half-portion of silica/MAO/toluene and left to react
5 for 2 hours with occasional mixing. The silica/MAO/Fe complex was washed with toluene (3 x 10 ml aliquots) at room temperature and then with hexane (2 x 10 ml aliquots) at room temperature to remove the toluene before finally being washed with hexane at 80°C (3 x 10 ml aliquots). The produced supported catalyst solid was dried under vacuum at room temperature. The solid contained 0.107 weight %
10 Fe.

37.2 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C. The reactor was cooled to less than 30°C and 500 ml of isobutane added. The reactor was heated to 77°C and the pressure increased to 13.8 bar. Ethylene was added to give
15 21.8 bar total pressure (8 bar ethylene). Triisobutyl aluminium (5 ml of 1M in hexanes) was added to the reactor and after 20 minutes the supported catalyst prepared in 37.1 above (0.14g in hexane slurry) was injected into the reactor and the pressure increase taken into account during control of the reactor pressure during the test. The temperature was increased to 80°C. After 5 hours the
20 polymerisation was terminated. 138g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 567000 and 53000 respectively. The produced polymer contained 1.02 ppm of Fe arising from the catalyst.

37.3 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 78°C. The reactor
25 was cooled to less than 30°C and 500 ml of isobutane added. Triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor which was then heated to 78°C and the pressure increased to 12.1 bar. Ethylene was added to give 32.0 bar total pressure (19.9 bar ethylene). The supported catalyst prepared in 37.1 above (0.0925g, slurried in hexane) was injected into the reactor and the total
30 pressure was controlled at 31.2 bar. The ethylene pressure during the polymerisation was estimated to be approximately 19.1 bar. Polymerisation was allowed to continue for 80 minutes. 181g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 595000 and 44000 respectively. The polymer contained 0.51 ppm of Fe arising from the catalyst.

35

37.4 - Polymerisation of Ethylene

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to less than 30°C. Triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor followed by 500 ml of isobutane. The reactor was heated to 78°C and the pressure increased to 13.5 bar. Ethylene was added to give 17.6 bar total pressure (4.1 bar ethylene). The supported catalyst prepared in 37.1 above (0.15g, slurried in hexane) was injected into the reactor. The ethylene pressure during the polymerisation was estimated to be approximately 4.7 bar. Polymerisation was allowed to continue for 80 minutes. 21g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 347000 and 26000 respectively.

Example 38

38.1 - Preparation of 2,6-diacetylpyridinebis(2,6 diisopropyl anil) cobalt dichloride supported on MAO/silica

The second half of the silica/MAO made in Example 37.1 was dried under vacuum. An aliquot of the dried silica/MAO (1g) was placed in to a Schlenk tube and 2,6-diacetylpyridinebis(2,6 diisopropyl anil) cobalt dichloride (40 mg) added to this as a dry powder. Hexane (10 ml) was then added to the Schlenk tube and the cobalt complex and silica/MAO slurried together for 1 hour at room temperature. The mixture was dried under vacuum at room temperature to leave the produced supported catalyst as a dry, free flowing powder.

38.2 - Polymerisation of ethylene

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to 30°C. Hexene (250 ml), triisobutyl aluminium (3 ml of 1M in hexanes) and 250 ml of isobutane were added to the reactor. The reactor was heated to 80°C and the pressure increased to 7.1 bar. Ethylene was added to give 19.2 bar total pressure (12.1 bar ethylene). The supported catalyst prepared in above (0.245g, slurried in hexane) was injected into the reactor and the pressure increase taken into account during control of the reactor pressure during the test. Polymerisation was allowed to continue for 330 minutes. 3.3g of polymer was recovered. Analysis of the polymer by GPC indicated Mw = 5300 and Mn = 1500.

Example 39 - Polymerisation of ethylene in slurry phase using a supported catalyst

A series of polymerisation tests was carried out using a catalyst based on a supported 2,6-diacetylpyridinebis(2,4,6 trimethyl anil) iron dichloride.

Example 39.1

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to 30°C. Isobutane (500ml) followed by triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor. The reactor was heated to 78°C and the pressure increased to 13.2 bar. Ethylene was added to give 26.2 bar total pressure. The catalyst of Example 37.1 (0.097g, slurried in hexane) was injected into the reactor. The reactor pressure was controlled at 26.0 bar during the test (ethylene pressure estimated to be approximately 12.8 bar) and the temperature adjusted to 80°C. Polymerisation was allowed to continue for 60 minutes. 78g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 528000 and 40000 respectively.

Example 39.2

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to 30°C. Isobutane (500ml) followed by triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor. The reactor was heated to 78°C and the pressure increased to 13.4 bar. Ethylene was added to give 21.2 bar total pressure. The catalyst of Example 37.1 (0.124g, slurried in hexane) was injected into the reactor. The ethylene pressure was estimated to be approximately 8.1 bar during the polymerisation and the temperature adjusted to 80°C. Polymerisation was allowed to continue for 60 minutes. 47g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 376000 and 40000 respectively.

Example 39.3

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to 30°C. Triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor followed by 500 ml of isobutane. The reactor was heated to 78°C and the pressure increased to 13.0 bar. Ethylene was added to give 26.0 bar total pressure. The catalyst of Example 37.1 (0.0966g, slurried in hexane and 0.25ml of NN dimethylaniline for 20 minutes) was injected into the reactor. The pressure in the reactor was allowed to fall to 22.5 bar to reduce the activity of the catalyst. The ethylene pressure in the reactor during the majority of the polymerisation was estimated to be 9.0 bar. Polymerisation was allowed to continue for 60 minutes. 88g of polymer was recovered. Analysis of the polymer by GPC indicated Mw and Mn to be 430000 and 35000 respectively.

Example 39.4

A 1 litre reactor was heated under flowing nitrogen for 1 hour at 80°C before being cooled to 30°C. Triisobutyl aluminium (3 ml of 1M in hexanes) was added to the reactor followed by 500 ml of isobutane. The reactor was heated to 78°C and the pressure increased to 12.7 bar. Ethylene was added to give 14.7 bar total pressure. The catalyst of Example 37.1 (0.104g, slurried in hexane) was injected into the reactor. The ethylene pressure during the polymerisation was estimated to be approximately 2.2 bar. Polymerisation was allowed to continue for 60 minutes. 4.8g of polymer was recovered. Analysis of the polymer by GPC indicated M_w and M_n to be 340000 and 36000 respectively.

Example 4040.1 Preparation of 2,6-diacetylpyridinebis(triphenylmethylimine)

To a solution of 2,6-diacetylpyridine (0.34 g; 2.1 mmol) in toluene (75 ml) was added triphenylmethylaniline (1.20 g; 4.6 mmol). After the addition of toluene sulphonic acid-monohydrate (0.05 g) the solution was refluxed overnight through a Dean-Stark apparatus. Upon cooling to room temperature the volatile components of the reaction mixture were removed *in vacuo* and the product crystallised from methanol. The product was filtered, washed with cold methanol and dried in a vacuum oven (30°C) overnight. The yield was 1.02 g (33 %).

40.2 Preparation 2,6-diacetylpyridinebis(triphenylmethylimine)FeBr₂

FeBr₂ (0.182 g; 0.84 mmol) was dissolved in hot n-butanol (30 ml) at 80°C and solid 2,6-diacetylpyridinebis(triphenylmethylaniline) (0.60 g; 0.93 mmol) was added in a number of portions. The reaction mixture turned purple. After stirring at 80°C for 60 minutes the reaction was allowed to cool down to room temperature. Stirring was continued for 25 hours. The volatile components of the solution were removed under reduced pressure and the resultant purple solid washed with pentane (2 x 20 cm³) and dried *in vacuo*. The yield was 0.362 g (64 % of theoretical).

40.3 Polymerisation Test

A polymerisation test was carried out using the following procedure. The 2,6-diacetylpyridinebis(triphenylmethylaniline)FeBr₂ catalyst (0.008 millimoles) was added to a Schlenk tube, suspended in toluene (15 ml) and methylalumoxane cocatalyst ("MAO") was added to provide a mole ratio of MAO: Fe complex of 1000:1. The tube was purged with ethylene and the contents were mechanically

- stirred and maintained under 1 bar ethylene for the duration of the polymerisation. After ninety minutes the polymerisation was terminated by the addition of aqueous hydrogen chloride. The produced solid polyethylene was filtered off, washed with methanol and dried in a vacuum oven at 50°C. The yield of polyethylene was
- 5 0.185g. This corresponds to a catalyst activity of $16 \text{ g mmol}^{-1}\text{h}^{-1}\text{bar}^{-1}$. No attempt was made to measure the quantity of any soluble polymer that may have been produced in this Example.

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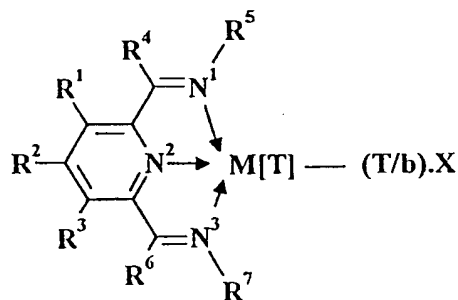
Claims

1. A polymerisation catalyst comprising

(1) a nitrogen-containing transition metal compound having the following Formula B, and

(2) an activating quantity of an activator compound selected from
5 organoaluminium compounds and hydrocarbylboron compounds,

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Formula B

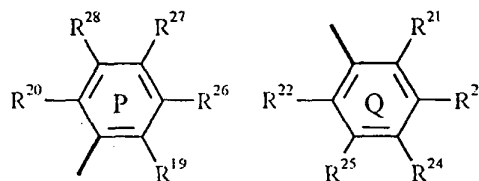
wherein M[T] is Fe[II], Fe[III], Co[I], Co[II], Co[III], Ru[II], Ru[III], Ru[IV],
Mn[I], Mn[II], Mn[III] or Mn[IV]; X represents an atom or group covalently or
20 ionically bonded to the transition metal M; T is the oxidation state of the transition
metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴, and R⁶
are independently selected from hydrogen, halogen, hydrocarbyl, substituted
hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl
and such that (1):
25 when M is Fe, Co or Ru, R⁵ and R⁷ are independently selected from hydrogen,

halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of $R^1 - R^7$ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents,

5 or such that (2):

when M is Fe, Co, Mn or Ru, then R^5 is represented by the group "P" and R^7 is represented by the group "Q" as follows:

10



wherein R^{19} to R^{28} are independently selected from hydrogen, halogen,

15 hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{19} to R^{28} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents; with the proviso that at least one of R^{19} , R^{20} , R^{21} and R^{22} is

20 hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl when neither of the ring systems P and Q forms part of a polyaromatic fused-ring system,

or such that (3)

when M is Fe, Co, Mn or Ru, then R^5 is a group having the formula $-NR^{29}R^{30}$ and

25 R^7 is a group having the formula $-NR^{31}R^{32}$, wherein R^{29} to R^{32} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{29} to R^{32} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be

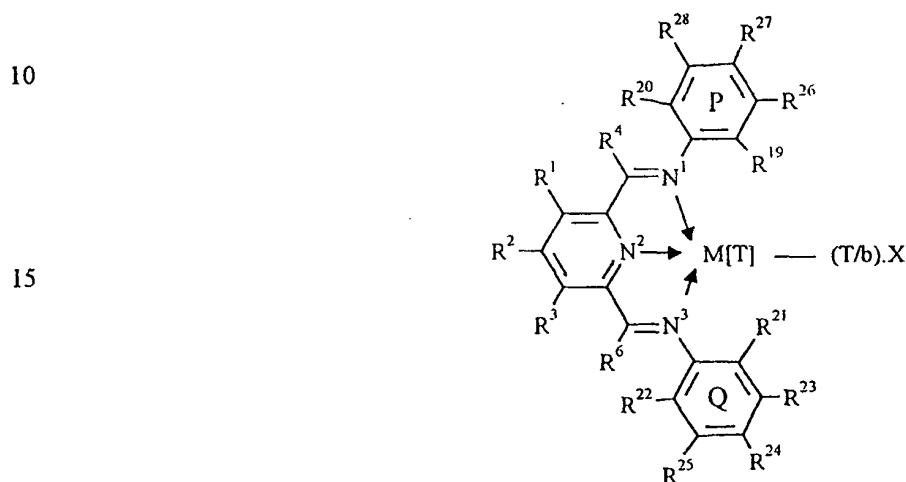
30 linked to form one or more cyclic substituents.

2. A catalyst as claimed in claim 1 wherein, in Formula B, $M[T]$ is $Fe[II]$, $Fe[III]$, $Ru[II]$, $Ru[III]$ or $Ru[IV]$; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R^1 , R^2 , R^3 , R^4 , R^5 , R^6 and R^7

35 are independently selected from hydrogen, halogen, hydrocarbyl, substituted

hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of $R^1 - R^7$ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

- 5 3. A catalyst as claimed in claim 1 wherein the Formula B compound has the following Formula Z



Formula Z

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R^1 to R^4 , R^6 and R^{19} to R^{28} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{19} to R^{28} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents; with the proviso that at least one of R^{19} , R^{20} , R^{21} and R^{22} is hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl when neither of the ring systems P and Q forms part of a polyaromatic fused-ring system.

4. A catalyst as claimed in Claim 3 wherein neither of the ring systems P and Q forms part of a polyaromatic ring system, and wherein at least one of R^{19} and

R^{20} , and at least one of R^{21} and R^{22} is selected from hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.

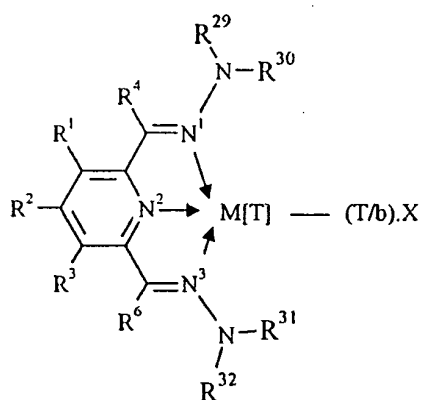
5. A catalyst as claimed in Claim 3 wherein neither of the ring systems P and Q forms part of a polyaromatic fused-ring system and wherein each of R^{19} , R^{20} ,

5 R^{21} and R^{22} is selected from hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.

6. A catalyst as claimed in claim 1 wherein the Formula B compound has the following Formula T

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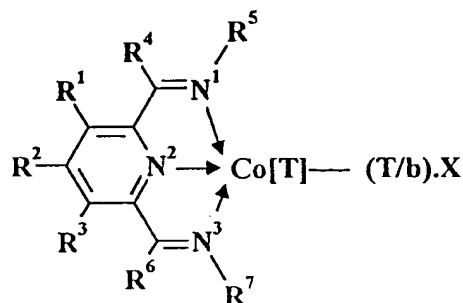
Formula T

and wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R^1 to R^4 , R^6 and R^{29} to R^{32} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{29} to R^{32} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

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7. A catalyst as claimed in Claim 1 wherein the Formula B compound has the following Formula W

35



Formula W

wherein X represents an atom or group covalently or ionically bonded to the cobalt atom; T is the oxidation state of the cobalt atom and can be Co[I], Co[II], Co[III], and b is the valency of the atom or group X; R¹, R², R³, R⁴, R⁵, R⁶ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; and when any two or more of R¹ - R⁷ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

8. A catalyst as claimed in any one of the preceding Claims wherein X is selected from halide, sulphate, nitrate, thiolate, thiocarboxylate, BF₄⁻, PF₆⁻, hydride, hydrocarbyloxy, carboxylate, hydrocarbyl, substituted hydrocarbyl and heterohydrocarbyl.

9. A catalyst as claimed in any one of Claims 1 to 7 wherein X is selected from chloride, bromide, methyl, ethyl, propyl, butyl, octyl, decyl, phenyl, benzyl, methoxide, ethoxide, isopropoxide, tosylate, triflate, formate, acetate, phenoxide and benzoate.

10. A catalyst as claimed in any one of the preceding claims wherein the organoaluminium compound is a trialkylaluminium compound.

11. A catalyst as claimed in any one of the preceding claims wherein the organoaluminium compound is an alumoxane.

12. A catalyst as claimed in any one of claims 1 to 9 wherein the hydrocarbylboron compound is selected from dimethylphenylammoniumtetra(phenyl)borate, trityltetra(phenyl)borate,

triphenylboron, dimethylphenylammonium tetra(pentafluorophenyl)borate, sodium tetrakis[(bis-3,5-trifluoromethyl)phenyl]borate, $H^+(OEt_2)[(bis-3,5-trifluoromethyl)phenyl]borate$, trityltetra(pentafluorophenyl)borate and tris(pentafluorophenyl) boron.

- 5 13. A catalyst as claimed in any one of the preceding Claims characterised in that the catalyst is supported on a support material.
14. A catalyst as claimed in Claim 13 wherein the support material is silica, alumina, or zirconia, or a polymer or prepolymer.
15. A catalyst as claimed in Claim 13 or 14 wherein formation of the supported
10 catalyst is achieved by treating the defined nitrogen-containing transition metal compound with alumoxane in a volatile hydrocarbon inert diluent, slurring a particulate support material with the product and evaporating the volatile diluent.
16. A catalyst as claimed in Claim 15 in the form of a free-flowing powder.
17. A catalyst system comprising the catalyst claimed in any one of the
15 preceding Claims and further comprising (3) a neutral Lewis base.
18. A catalyst system comprising the catalyst claimed in Claim 17 wherein the neutral Lewis base is a tertiary amine or an aromatic ester.
19. A process for the polymerisation or copolymerisation of 1-olefins comprising contacting the monomeric olefin under polymerisation conditions with
20 the polymerisation catalyst claimed in any one of the preceding Claims.
- 20 A process as claimed in Claim 19 wherein the monomer is ethylene, propylene, butene, hexene, methyl methacrylate, methyl acrylate, butyl acrylate, acrylonitrile, vinyl acetate or styrene.
21. A process as claimed in Claim 19 wherein the process is for the
25 homopolymerisation of ethylene or propylene.
22. A process as claimed in Claim 19 wherein ethylene is copolymerised with another 1-olefin selected from propylene, 1-butene, 1-hexene, 4-methylpentene-1, and octene
- 23 A process as claimed in any one of Claims 19 to 22 wherein hydrogen gas
30 is added to the polymerisation to control the average molecular weight of the produced polymer.
24. A process as claimed in any one of Claims 19 to 23 wherein the polymerisation temperature is in the range 50 to 120°C and the pressure is in the range 10 to 50 bar.
- 35 25. A process as claimed in Claim 19 wherein the polymerisation conditions are

solution phase, slurry phase or gas phase.

26. A process as claimed in Claim 19 wherein the polymerisation is conducted under gas phase fluidised bed conditions.

27. A process as claimed in Claim 26 wherein volatile liquid is fed to the fluidised bed under conditions such that the liquid evaporates in the bed thereby absorbing additional heat of polymerisation from the bed.

28. A process as claimed in Claim 27 wherein the volatile liquid is condensed out in a heat exchanger.

29. A process as claimed in Claim 28 wherein said volatile liquid is separated from the recycle gas.

30. A process as claimed in Claim 29 wherein said volatile liquid is sprayed into the bed.

31. A process as claimed in Claim 28 wherein said volatile liquid is recycled to the bed with recycle gas.

32. A process as claimed in Claim 26 wherein hydrogen gas is added to the polymerisation to control the average molecular weight of the produced polymer.

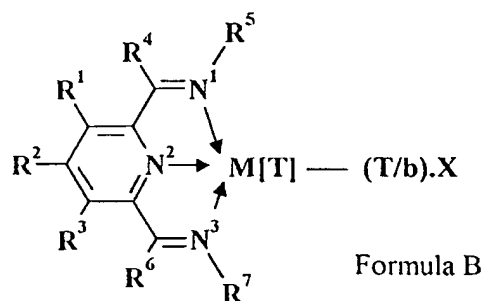
33. A process as claimed in Claim 26 wherein the polymerisation temperature is in the range 50 to 120°C and the pressure is in the range 10 to 50 bar.

34. Polyethylene powder containing a catalyst comprising a nitrogen-containing Fe complex wherein the Fe concentration is 1.03 to 0.11 parts by weight of Fe per million parts by weight of polyethylene.

35. Polyethylene powder as claimed in Claim 34 wherein the catalyst is the catalyst claimed in any one of Claims 1 to 16.

36. Polyethylene powder as claimed in Claim 34 wherein the complex is obtainable from a nitrogen-containing transition metal compound of Formula B as defined in Claim 1.

37. A nitrogen-containing transition metal compound comprising the skeletal unit depicted in Formula B



wherein M is Fe[II], Fe[III], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹, R², R³, R⁴ and R⁶ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; R⁵ and R⁷ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.

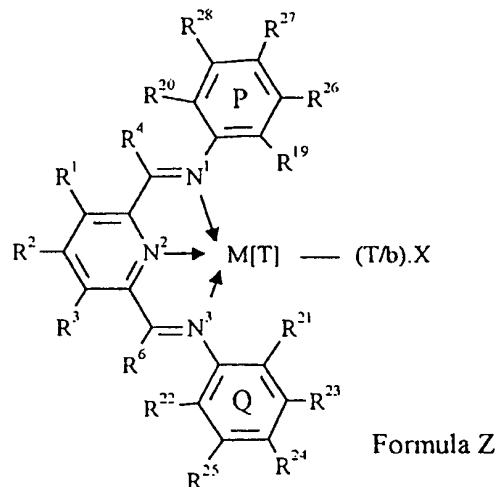
38. A nitrogen-containing transition metal compound as claimed in Claim 37 wherein R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from hydrogen and C₁ to C₈ hydrocarbyl.

39. A nitrogen-containing transition metal compound as claimed in Claim 37 or 38 wherein R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from methyl, ethyl, n-propyl, n-butyl, n-hexyl, and n-octyl.

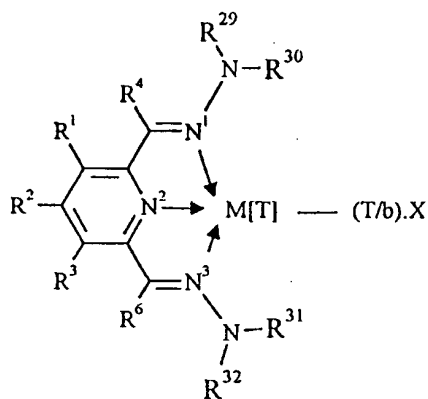
40. A nitrogen-containing transition metal compound as claimed in Claim 37, 38 or 39 wherein R⁵ and R⁷ are independently selected from phenyl, 1-naphthyl, 2-naphthyl, 2-methylphenyl, 2-ethylphenyl, 2,6-diisopropylphenyl, 2,3-diisopropylphenyl, 2,4-diisopropylphenyl, 2,6-di-n-butylphenyl, 2,6-dimethylphenyl, 2,3-dimethylphenyl, 2,4-dimethylphenyl, 2-t-butylphenyl, 2,6-diphenylphenyl, 2,4,6-trimethylphenyl, 2,6-trifluoromethylphenyl, 4-bromo-2,6-dimethylphenyl, 3,5 dichloro-2,6-diethylphenyl, and 2,6-bis(2,6-dimethylphenyl)phenyl, cyclohexyl and pyridinyl.

41. The complex 2,6-diacetylpyridinebis(2,4,6-trimethylanil)FeCl₂.

42. A nitrogen-containing transition metal compound comprising the skeletal unit depicted in Formula Z:



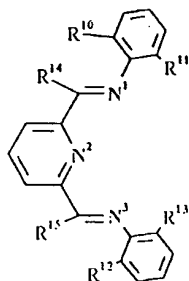
- wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III], Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or ionically bonded to the transition metal M; T is the oxidation state of the transition metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents; with the proviso that at least one of R¹⁹, R²⁰, R²¹ and R²² is hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl when neither of the ring systems P and Q forms part of a polyaromatic fused-ring system.
43. A nitrogen-containing transition metal compound as claimed in Claim 42 wherein R¹ to R⁴, R⁶ and R¹⁹ to R²⁸ are independently selected from hydrogen and C₁ to C₈ hydrocarbyl, for example, methyl, ethyl, n-propyl, n-butyl, n-hexyl, and n-octyl.
44. A nitrogen-containing transition metal compound as claimed in Claim 42 wherein and at least one of R¹⁹ and R²⁰, and at least one of R²¹ and R²², is selected from hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl and wherein neither of the ring systems P and Q forms part of a polyaromatic ring system.
45. A nitrogen-containing transition metal compound as claimed in Claim 42 wherein R¹⁹, R²⁰, R²¹ and R²² are each selected from hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl.
46. A nitrogen-containing transition metal compound comprising the skeletal unit depicted in Formula T:



Formula T

wherein M is Fe[II], Fe[III], Co[I], Co[II], Co[III], Mn[I], Mn[II], Mn[III],
 15 Mn[IV], Ru[II], Ru[III] or Ru[IV]; X represents an atom or group covalently or
 ionically bonded to the transition metal M; T is the oxidation state of the transition
 metal M and b is the valency of the atom or group X; R¹ to R⁴, R⁶ and R²⁹ to R³²
 are independently selected from hydrogen, halogen, hydrocarbyl, substituted
 hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or
 20 more of R¹ to R⁴, R⁶ and R²⁹ to R³² are hydrocarbyl, substituted hydrocarbyl,
 heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be
 linked to form one or more cyclic substituents.

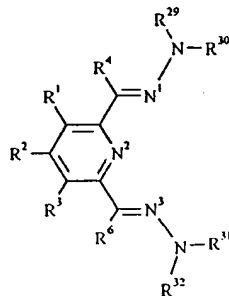
47. A compound having the general Formula E as follows:



Formula E

wherein R^{10} , R^{11} , R^{12} and R^{13} are independently selected from C_1 to C_{20} hydrocarbon groups; and R^{14} , R^{15} and all the remaining ring substituents on the pyridine and benzene rings depicted in Formula E are independently selected from hydrogen and C_1 to C_{20} hydrocarbon groups.

- 5 48. A compound having the general Formula P as follows:



Formula P

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wherein R^1 to R^4 , R^6 and R^{29} to R^{32} are independently selected from hydrogen, halogen, hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl; when any two or more of R^1 to R^4 , R^6 and R^{29} to R^{32} are hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl or substituted heterohydrocarbyl, said two or more can be linked to form one or more cyclic substituents.

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49. Use of a compound as defined in any one of claims 37 to 48 as a catalyst for the polymerisation or co-polymerisation of 1-olefins.

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INTERNATIONAL SEARCH REPORT

national Application No

PCT/GB 98/02638

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 C08F4/70 C07D213/53 C07F15/02 C07F15/06 C08F10/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 C08F C07F C07D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 98 27124 A (DU PONT) 25 June 1998	1-5, 19-21, 24,25
P,X	see examples 16,20	1,3-5, 7-11
P,X	see examples 7,60	12
P,X	see examples 43-45	13,14
P,X	see examples 15,24	2
P,X	see example 18	49
P,X	see examples 8,9	37,40, 42-45
P,X	see example 5	47

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

7 December 1998

Date of mailing of the international search report

20. 01. 1999

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INTERNATIONAL SEARCH REPORT

national Application No
PCT/GB 98/02638

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	<p>BIRTOVSEK, GEORGE J. P. ET AL: "Novel olefin polymerization catalysts based on iron and cobalt" CHEM. COMMUN. (CAMBRIDGE) (1998), (7), 849-850 CODEN: CHCOFS;ISSN: 1359-7345, XP002086893</p> <p>see the whole document</p> <p style="text-align: center;">---</p>	<p>1-5, 7-11, 19-21, 24,25, 37, 40-45, 47,49</p>
P,X	<p>SMALL, BROOKE L. ET AL: "New iron and cobalt catalysts for the polymerization of olefins" POLYM. PREPR. (AM. CHEM. SOC., DIV. POLYM. CHEM.) (1998), 39(1), 213 CODEN: ACPPAY;ISSN: 0032-3934, XP002086894</p> <p>see the whole document</p> <p style="text-align: center;">---</p>	<p>1-5,7-9, 19-21, 37,40, 42-45, 47,49</p>
P,X	<p>GUERIN, FREDERIC ET AL: "Ortho-substituted aryl diamido complexes of zirconium: observation of rotameric isomers" POLYHEDRON (1998), 17(5-6), 917-923 CODEN: PLYHDE;ISSN: 0277-5387, XP002086895</p> <p>see page 918; figure 1; example D</p> <p style="text-align: center;">---</p>	<p>47</p>
X	<p>CURRY, JOHN D. ET AL: "Metal complexes derived from substituted hydrazones of 2,6-diacetylpyridine" INORG. CHEM. (1967), 6(8), 1570-4 CODEN: INOCAJ, XP002086896</p> <p>see abstract see page 1570, column 2, paragraph 3 - page 1571, column 1, line 2: figure V see table I see page 1572, column 1, paragraph 14 - column 2: figure VI</p> <p style="text-align: center;">---</p>	<p>46,48</p>
X	<p>BONARDI, ALEX ET AL: "Copper(II), nickel(II) and iron(II) complexes of 2,6-diacetylpyridine bis[DL-hydroxy(phenyl)acetic!hydrazonol. x-ray structure of a 1:2 metal:ligand nickel complex" INORG. CHIM. ACTA (1995), 232(1-2), 211-16 CODEN: ICHAA3;ISSN: 0020-1693, XP002086897</p> <p>see page 211 see page 215; examples 5-7; table 3</p> <p style="text-align: center;">---</p>	<p>37,46,48</p>
X	<p>PATENT ABSTRACTS OF JAPAN vol. 014, no. 270 (C-0727), 12 June 1990 & JP 02 078663 A (N O K SOGO GIJUTSU KENKYUSHO:KK), 19 March 1990</p> <p>see abstract</p> <p style="text-align: center;">---</p> <p style="text-align: center;">-/--</p>	<p>42,43</p>

INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	<p>SMALL, BROOKE L. ET AL: "Iron-Based Catalysts with Exceptionally High Activities and Selectivities for Oligomerization of Ethylene to Linear.alpha.-Olefins"</p> <p>J. AM. CHEM. SOC. (1998), 120(28), 7143-7144 CODEN: JACSAT;ISSN: 0002-7863, XP002086898</p> <p>see page 7143, column 1, paragraph 2 - paragraph 3</p> <p style="text-align: center;">---</p>	34-36
X	<p>BLANDAMER, MICHAEL J. ET AL:</p> <p>"Solubilities of salts and kinetics of reaction between hydroxide ions and iron(II)-diimine complexes in water-methanol mixtures. Derivation of single-ion transfer chemical potentials and their application to analysis of solvent effects on kinetic parameters"</p> <p>J. CHEM. SOC., FARADAY TRANS. 1 (1986), 82(5), 1471-514 CODEN: JCFTAR;ISSN: 0300-9599,1986, XP002086899</p> <p>see page 1474; examples TSB-H</p> <p>see page 1485; example 9; table 2</p> <p style="text-align: center;">-----</p>	37,40

INTERNATIONAL SEARCH REPORT

International application No.
PCT/GB 98/02638

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 38, 39
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:

In claims 38 and 39, the definition of R19 to R28 is given whereas these substituents R19 to R28 do not even appear in claim 37 on which claims 38 and 39 are depending.

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No

PCT/GB 98/02638

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9827124 A	25-06-1998	AU 5711098 A	15-07-1998

